UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ENHANCING BATTERY LIFE AND SAFETY IN REMOTE CONTROL CARS THROUGH REAL-TIME IoT MONITORING SYSTEM

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SURENDRAN A/L BALAKRISHNAN

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

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2023

DECLARATION

I declare that this Choose an item.entitled “Enhancing Battery life and Safety Remote Control Cars Through Real Time IoT Monitoring System: This Project is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved parent, Balakrishnan A/L Muniandy, for your patience and My mother Rajakumari A/P Periasamy everything with love. To my family members and friends for their continuous support and encouragement while I have been away from home.

ABSTRACT

This project aims to enhance battery life and safety in remote control cars through the implementation of a real-time Internet of Things (IoT) monitoring system. By addressing the limitations posed by battery-related issues, the project seeks to provide users with a user-friendly and effective battery monitoring system that enables real-time monitoring and analysis of battery health parameters. The literature review explores the history of batteries, different types of batteries used in remote control cars, and fundamental principles of battery technology. Following a careful evaluation, lithium-ion batteries are selected for this project due to their advantages. The scope of the project encompasses the design and development of an IoT-based battery monitoring system tailored for remote control cars, utilizing sensor modules to measure critical battery health parameters. Real-time data transmission to a user interface will provide valuable insights for informed decision-making regarding charging and replacement. The methodology involves the integration of appropriate sensors, microcontrollers, and communication protocols, followed by rigorous testing to validate system performance. The anticipated outcomes include improved battery life, enhanced safety, and optimized performance, empowering users to extend battery lifespan and prevent safety hazards.

ABSTRAK

Projek ini bertujuan untuk meningkatkan jangka hayat dan keselamatan bateri dalam kereta kawalan jauh melalui pelaksanaan sistem pemantauan Internet of Things (IoT) secara masa nyata. Dengan menangani masalah berkaitan bateri, projek ini bertujuan untuk menyediakan pengguna dengan sistem pemantauan bateri yang mudah digunakan dan berkesan yang membolehkan pemantauan dan analisis bateri secara masa nyata. Kajian literatur meneroka sejarah bateri, jenis-jenis bateri yang digunakan dalam kereta kawalan jauh, dan prinsip-prinsip asas teknologi bateri. Selepas penilaian yang teliti, bateri lithium-ion dipilih untuk projek ini kerana kelebihannya. Skop projek merangkumi reka bentuk dan pembangunan sistem pemantauan bateri berasaskan IoT yang disesuaikan untuk kereta kawalan jauh, dengan menggunakan modul sensor untuk mengukur parameter kesihatan bateri yang penting. Penghantaran data secara masa nyata ke antara muka pengguna akan memberikan pandangan berharga untuk membuat keputusan yang berinformasi mengenai pengecasan dan penggantian. Metodologi melibatkan integrasi sensor yang sesuai, mikrokontroler, dan protokol komunikasi, diikuti dengan ujian yang teliti untuk memastikan prestasi sistem. Hasil yang dijangka termasuk peningkatan jangka hayat bateri, peningkatan keselamatan, dan prestasi yang dioptimum, memperkuatkan pengguna untuk memanjangkan jangka hayat bateri dan mencegah bahaya keselamatan.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background

Remote control cars have become increasingly popular over the years, particularly among hobbyists and enthusiasts [1] These vehicles are powered by batteries, which can be a major limiting factor in terms of performance and usability. A dead or malfunctioning battery can quickly bring a remote control car to a halt, and improperly maintained batteries can pose a safety risk.

In order to address these issues, a real-time IoT battery monitoring system can be implemented to enhance battery life and safety in remote control cars. This system can provide users with valuable information about the health of their batteries, allowing them to make informed decisions about when to charge or replace them[2]

The increasing popularity of remote control cars has resulted in a growing demand for higher performance and greater functionality. However, these improvements often come at the cost of increased power consumption, leading to shorter battery life and greater risk of battery failure. Additionally, the use of lithium-ion batteries in remote control cars can pose a significant safety risk if not properly monitored and maintained. Therefore, the development of a real-time IoT battery monitoring system for remote control cars can not only improve their performance and usability but also enhance their safety and reliability[3]This project aims to address these issues by providing users with a user-friendly and effective battery monitoring system that can help them make informed decisions about their batteries.

In recent years, there has been a growing trend towards the adoption of Internet of Things (IoT) technology in various industries. IoT enables the connectivity and exchange of data between devices and systems, providing real-time monitoring and control capabilities. Applying IoT to the field of remote control cars opens up new possibilities for enhancing battery life and safety. By integrating sensors, wireless communication, and data analysis techniques, a real-time IoT monitoring system can continuously monitor the battery parameters and provide valuable insights to users[4]. This not only improves the overall performance and reliability of remote control cars but also contributes to the advancement of IoT applications in the automotive domain.

Battery life is a critical factor in the usability and enjoyment of remote control cars. Long-lasting batteries ensure extended playtime and minimize the downtime required for recharging or battery replacement. Additionally, optimizing battery life reduces the environmental impact associated with frequent battery disposal and promotes sustainable practices. By developing a real-time IoT monitoring system, the project aims to enhance battery life by providing users with accurate and up-to-date information on the battery's health and performance.

1.2 Problem Statement

The problem with current remote control car batteries is that they are often not monitored closely enough, which can lead to premature battery failure and safety hazards. Many remote control car users are unaware of how to properly maintain and monitor their batteries, leading to suboptimal performance and potential safety risks. Therefore, there is a need for an effective and easy-to-use battery monitoring system that can help users to extend the life of their batteries and reduce the risk of safety hazards. For example, lithium-ion batteries are susceptible to overcharging, which can cause them to catch fire or explode. In addition, the degradation of battery health over time can result in reduced performance and increased safety risks.

To support this statement, research studies such as "Battery Management Systems for Electric Vehicles" by [5] have highlighted the importance of effective battery monitoring systems in ensuring the safety and performance of electric vehicles, which includes remote control cars.[6]. Furthermore, articles such as "Lithium-ion batteries: basics, progress, and challenges" by Venkat Srinivasan and "Lithium-ion batteries: unsafe unless designed with safety in mind" by [8] discuss the safety concerns associated with lithium-ion batteries, emphasizing the importance of proper monitoring and maintenance.

Inadequate battery maintenance and monitoring procedures in remote control cars present serious difficulties. Many users lack the skills and resources necessary to properly monitor their battery's health and performance, which causes early battery failure and poorer overall performance. Users cannot identify potential problems like overcharging, which can pose a safety risk, without real-time monitoring. The user experience is hampered by the lack of a thorough battery monitoring system, which also puts performance, dependability, and longevity of remote control cars at a disadvantage[9]

Furthermore, users of remote control cars may incur unnecessary costs as a result of improper battery monitoring systems. Users may adopt conservative charging techniques, frequently recharging the battery even when it is not necessary, if they are not provided with accurate information about the battery's state of charge and health. Due to the frequent charge-discharge cycles, this not only increases electricity consumption but also reduces the battery's lifespan. On the other hand, users might unintentionally push the battery to its breaking point, causing early deterioration and decreased capacity. By giving users precise data and useful insights, a well-designed and implemented real-time IoT monitoring system can address these problems by empowering users to optimise battery usage, increase battery life, and cut down on unnecessary expenses.

1.3 Objective

The objective of this project is to design and develop a real-time IoT battery monitoring system for remote control cars. The system will provide users with real-time information about the health of their batteries, allowing them to make informed decisions about charging or replacing them. The system will also include safety features to prevent overcharging, short-circuiting, and other potential safety hazards. Specifically, the project aims to:

1. Study the existing literature and research on battery monitoring systems and IoT applications in remote control cars to gain a thorough understanding of the project scope and relevant technologies and analyse also check parameter of Lithium-ion (Li-ion) Battery.

2. Design and implement a sensor module that can measure critical battery health parameters such as voltage, current, and temperature accurately and reliably.

3. Develop a real-time data acquisition system to collect battery health information from the sensor module and transmit it wirelessly to a central monitoring unit.

4. Evaluate the effectiveness of the system in enhancing battery life and safety in remote control cars through field tests and experiments.

1.4 Scope

1. The project will focus on the design and implementation of an IoT-based battery monitoring system for remote control cars.

2. The system will be designed to improve battery life and safety by providing real-time monitoring of battery health and performance.

3. The project will explore different battery monitoring techniques such as voltage, current, and temperature sensing to obtain accurate battery health and performance data.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of the literature related to battery monitoring systems and IoT applications for remote control cars. The literature review aims to identify the current state of the art in battery monitoring systems, including the types of sensors and monitoring techniques used. Additionally, it will explore the potential benefits and limitations of implementing IoT technology in remote control cars, specifically in relation to battery monitoring.

2.1.1 Battery Monitoring Systems

Battery monitoring systems have been extensively studied and developed for various applications such as electric vehicles, renewable energy systems, and aerospace technology. The basic purpose of battery monitoring systems is to measure various battery parameters such as voltage, current, and temperature, to obtain information about the state of the battery. The information obtained from these sensors can be used to determine the battery's health and performance, which is essential for ensuring its safety and optimal performance[10]

Battery monitoring systems play a vital role in enhancing the battery life and safety of remote control cars. Extensive research has been conducted on different approaches to develop effective battery monitoring systems, including wired, wireless, and IoT-based solutions. Wired systems typically utilize voltage and current sensors that are connected to a central processing unit, enabling real-time monitoring of critical battery parameters[4].

2.1.2 IoT Applications for Remote Control Cars

The Internet of Things (IoT) technology has been increasingly used in remote control car applications, offering various benefits such as increased performance, better control, and improved safety. IoT technology can be used in remote control cars for various applications such as telemetry, tracking, and remote control. In terms of battery monitoring, IoT-based systems offer the advantage of real-time monitoring of battery parameters, which can help improve battery life and safety[5]

2.2 Battery

2.2.1 History

The history of batteries dates back to the late 1700s, when Italian physicist Alessandro Volta invented the first battery, known as the Voltaic Pile, in 1800. This battery consisted of alternating layers of zinc and copper discs separated by cardboard soaked in saltwater or acid, which generated a steady flow of electricity[11]

Over the next century, various types of batteries were developed, such as the Daniell cell, Grove cell, and Leclanché cell. These batteries used different materials and electrolytes to generate electricity and were used in various applications, such as telegraphy, lighting, and medical devices.

In the 20th century, the development of portable electronics and communication devices drove the demand for smaller, lighter, and more efficient batteries. This led to the commercialization of the alkaline battery in the 1950s, followed by the rechargeable nickel-cadmium (Ni-Cd) battery in the 1960s and the nickel-metal hydride (Ni-MH) battery in the 1980s[12]

In the 1990s, the lithium-ion (Li-ion) battery was introduced, which revolutionized the battery industry due to its high energy density and rechargeability. Today, Li-ion batteries are widely used in various applications, including electric vehicles, portable electronics, and renewable energy systems[13], [14]

Overall, the history of batteries shows a continuous evolution and innovation to meet the demands of various applications, including the power needs of remote control cars[12]

2.2.2 Fundamental of battery technology

Battery technology plays a crucial role in powering a wide range of devices, from electric cars to portable electronics, making it an indispensable aspect of modern society. To optimize battery performance, ensure safety, and unlock new possibilities in various applications, having a solid understanding of battery fundamentals is vital [15]

One of the key factors in battery technology is battery chemistry, which refers to the specific chemical composition used in different battery types. Popular battery chemistries include lead-acid, nickel-cadmium (Ni-Cd), nickel-metal-hydride (Ni-MH), and lithium-ion (Li-ion) batteries, each with its own strengths and limitations. Factors like energy density, power density, and cost-effectiveness determine the suitability of a particular chemistry for specific applications[16].

1. Battery capacity is another important aspect, representing the amount of energy a battery can store. Capacity is typically measured in ampere-hours (Ah) or watt-hours (Wh) and can vary depending on factors like battery chemistry, size, and quality[17].

2. Cycle life refers to the number of charge and discharge cycles a battery can undergo before experiencing a significant decrease in capacity. Different battery types have varying cycle lives, which can be influenced by variables like temperature and depth of discharge[18].

3. Charging is the process of adding energy to a battery, and it is essential to follow the appropriate charging requirements for each battery chemistry. Incorrect charging practices, such as overcharging or undercharging, can result in safety risks and reduced battery lifespan[19].

4. Battery safety is of utmost importance to prevent potential hazards. Proper design, manufacturing, and usage are crucial to avoid issues like overcharging, short-circuiting, and thermal runaway, which can lead to fires, explosions, or other dangerous situations[20].

2.2.3 Type of Batteries

There are various types of batteries that are commonly used in remote control cars and other electronic devices. Some of the most commonly used batteries include:

1. Nickel-Cadmium (NiCd) batteries: These batteries are known for their high capacity, long cycle life, and relatively low cost. However, they are also prone to memory effect, which can lead to reduced capacity over time[21] Below figure 1 shows the picture of Nickel-Cadmium Battery.

Figure 1 : Nickel-Cadmium (NiCd) batteries[21]

2. Nickel-Metal Hydride (NiMH) batteries: These batteries are an improved version of NiCd batteries and offer higher capacity, longer cycle life, and no memory effect. They are also relatively low-cost, making them a popular choice for remote control cars[22] Below figure 2 shows the picture of Nickel-Metal Hydride.

Figure 2 : Nickel-Metal Hydride (NiMH) batteries[21]

3. Lithium-ion (Li-ion) batteries: These batteries are known for their high energy density, which allows them to deliver more power for a given size and weight compared to other battery types. They also have a long cycle life and no memory effect. However, they can be more expensive and require careful monitoring and maintenance to prevent safety hazards.[8], [23] Below figure 3 shows the picture of Lithium Ion Battery.

Figure 3 : Lithium-ion (Li-ion) batteries[11]

4. Lithium Polymer (LiPo) batteries: These batteries are a type of Li-ion battery that uses a flexible polymer electrolyte instead of a liquid electrolyte. They offer even higher energy density and lighter weight compared to traditional Li-ion batteries. However, they require even more careful monitoring and maintenance to prevent safety hazards[24] Below figure 4 shows the picture of lithium polymer battery.

Figure 4 : Lithium Polymer (LiPo) batteries[25]

Other types of batteries that may be used in remote control cars include lead-acid batteries and alkaline batteries, although these are less commonly used compared to the above types.

2.3 Lithium-ion (Li-ion) Battery

2.3.1 Background and History

Lithium-ion (Li-ion) batteries are rechargeable batteries that are commonly used in a wide range of electronic devices such as laptops, smartphones, and electric vehicles. Here's a brief background and history of the Li-ion battery[26].

Before the development of Li-ion batteries, other types of rechargeable batteries were used, such as nickel-cadmium (Ni-Cd) and nickel-metal-hydride (Ni-MH) batteries. These batteries were heavy, had a low energy density, and had a tendency to lose their charge over time, making them less efficient.

The Li-ion battery was first developed in the 1970s by a British chemist named Stanley Whittingham. However, it was not until the 1990s that the Li-ion battery became commercially viable, thanks to the work of John B. Goodenough, who helped to develop a cathode material that greatly improved the battery's energy density. In the early 2000s, the Li-ion battery became the battery of choice for many portable electronic devices due to its high energy density, low self-discharge rate, and longer lifespan compared to other types of batteries[27].

Over the years, Li-ion battery technology has continued to improve, with advancements in electrode materials, electrolytes, and cell design. Today, Li-ion batteries are widely used in electric vehicles, renewable energy storage systems, and other applications that require high energy density and long-lasting power. Below figure 5 shows the picture of lithium ion battery[28].

Figure 5 : Lithium-Ion Battery[23]

2.3.2 Components Of A Lithium-Ion Cell

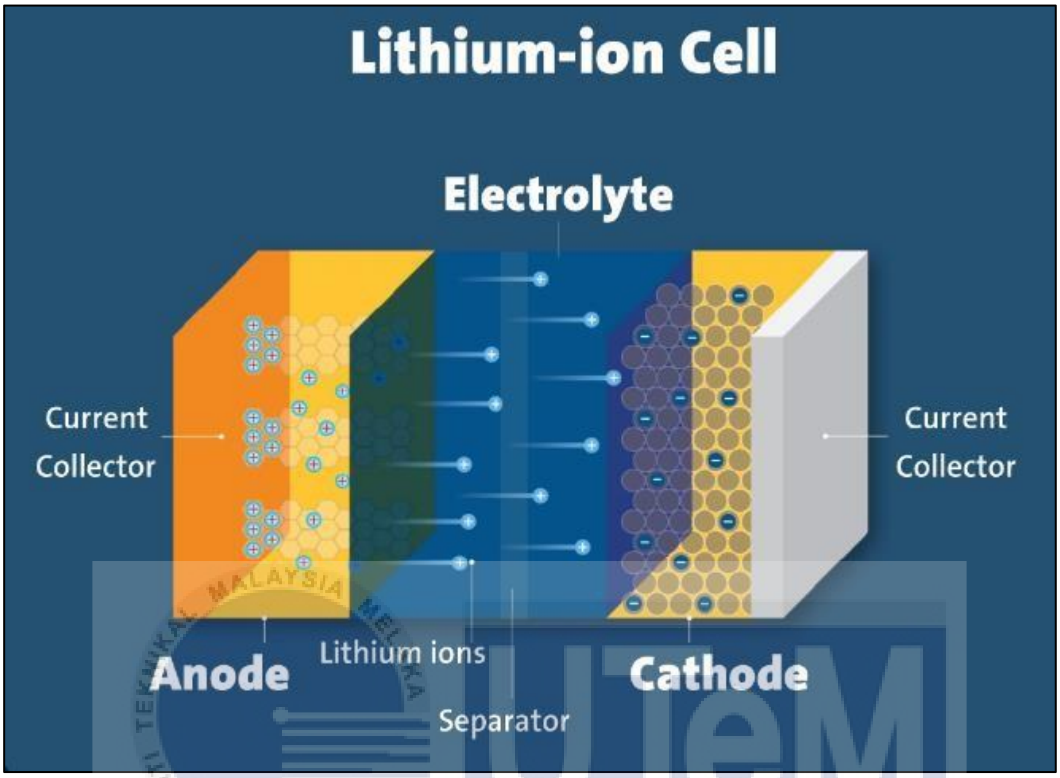


Figure 6 : Components of a lithium-Ion[11]

Table 1 : Components of Lithium

TERM	DEFINITION
Electrodes[29]	The positively and negatively charged ends of a cell. Attached to the current collectors.
Anode[30]	The negative electrode
Cathode[31]	The positive electrode
Electrolyte[29]	A liquid or gel that conducts electricity
Current Collectors[32]	Conductive foils at each electrode of the battery that are connected to the terminals of the cell. The cell terminals transmit the electric current between the battery, the device and the energy source that powers the battery.
Separator[33]	A porous polymeric film that separates the electrodes while enabling the exchange of lithium ions from one side to the other.

2.3.3 The way of lithium-Ion cell works

In a lithium-ion battery, an internal movement of lithium ions (Li+) occurs between the cathode and anode. Simultaneously, electrons flow in the opposite direction through the external circuit, creating the electric current that powers the device[31].

During discharge, the anode releases lithium ions to the cathode, generating an electron flow that supplies power to the device. Conversely, during charging, the cathode releases lithium ions, which are then received by the anode[5].

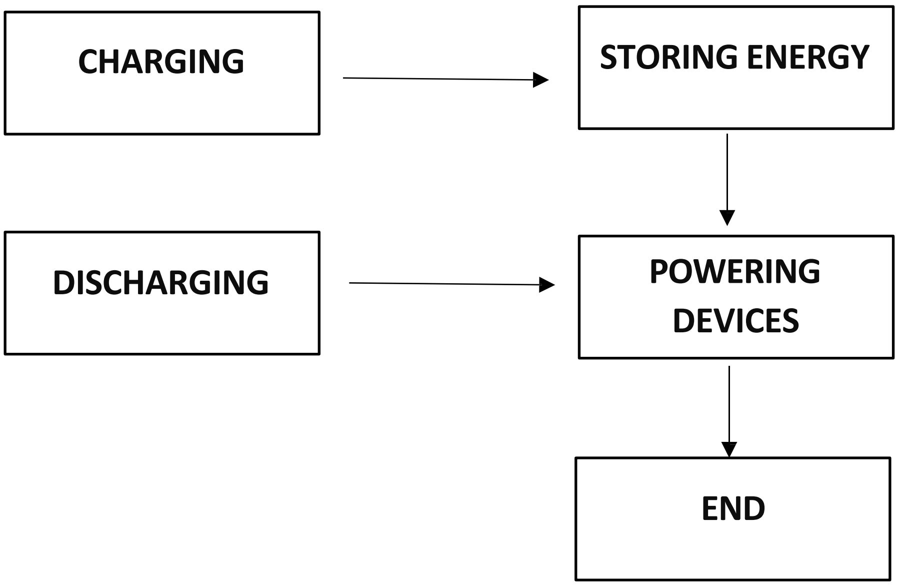
The operation of a lithium-ion (Li-ion) cell involves the movement of lithium ions between the cathode and anode to store and release energy. Here is a simplified explanation of how it functions[32]:

1. Charging: When a Li-ion cell is charged, lithium ions move from the cathode (positive electrode) to the anode (negative electrode) through the electrolyte. This process is facilitated by an external power source that applies a voltage to the cell.

2. Energy Storage: As lithium ions migrate to the anode, they are stored within the crystal lattice structure of the anode material, typically graphite. This ion movement leads to an accumulation of electrons at the anode, resulting in a negative charge.

3. Discharging: When the cell is in use (discharged), the process is reversed. Lithium ions move from the anode to the cathode through the electrolyte, releasing the stored energy. This ion flow causes an accumulation of electrons at the cathode, resulting in a positive charge.

4. Powering Devices: The movement of electrons between the anode and cathode generates an electric current that can be utilized to power electronic devices.



2.4 Battery Comparison

Table 2 : Battery Comparison Factors

TYPE OF BATTERY	**Nickel-Cadmium (NiCd) [21]**	**Nickel-Metal Hydride (NiMH)[21]**	**Lithium-ion (Li-ion)[11]**	**Lithium Polymer (LiPo)[34]**
MAXIMUM ENERGY DENSITY	60 Wh/Kg	120 Wh/Kg	265 Wh/Kg	250 Wh/Kg
CYCLE LIFE	500-1,000 Cycles	500-1,000 Cycles	500-1,500 Cycles	300-500 Cycles
MEMORY EFFECT	High Memory Effect	Moderate Memory Effect	Low To No Memory Effect	Low To No Memory Effect
SAFETY	Moderate Safety	Moderate Safety	High Safety	High Safety

2.4.1 Maximum Energy Density

Note that these values can vary depending on the specific type and configuration of the battery, as well as the manufacturing process. However, in general, lithium-ion and lithium polymer batteries have a higher energy density than NiCd and NiMH batteries, which makes them ideal for applications where weight and space are critical, such as portable electronic devices and electric vehicles[35]

The maximum energy density of a battery refers to the amount of energy that can be stored in a given volume or weight of the battery. It is an important parameter as it determines the amount of energy a battery can provide per unit of volume or weight. It should be noted that the values of energy density can vary depending on the specific type and configuration of the battery, as well as the manufacturing process

In general, lithium-ion and lithium polymer batteries tend to exhibit higher energy densities compared to nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries. This characteristic makes lithium-based batteries particularly well-suited for applications where weight and space considerations are crucial, such as in portable electronic devices and electric vehicles[36]

Lithium-ion and lithium polymer batteries achieve their higher energy density through the use of lithium-based compounds in their electrodes, which provide a higher voltage and greater energy storage capacity compared to the nickel-based chemistries used in NiCd and NiMH batteries.

2.4.2 Cycle Life

Note that the cycle life of a battery depends on several factors, such as depth of discharge, temperature, and charging/discharging rates. In general, lithium-ion batteries have a longer cycle life than NiCd and NiMH batteries, which makes them more cost-effective in the long run. However, the specific cycle life of a battery can vary depending on its quality, usage, and maintenance.[37], [38]

The cycle life of a battery refers to the number of charge and discharge cycles it can undergo before its capacity significantly degrades. Several factors influence the cycle life of a battery, including the depth of discharge (DoD), temperature, and charging/discharging rates.

Depth of discharge refers to the amount of the battery's capacity that is utilized during each discharge cycle. Generally, batteries that are discharged to a lower DoD tend to have longer cycle lives. For example, if a battery is consistently discharged to only 20% of its capacity before recharging, it may have a longer cycle life compared to a battery that is discharged to 80% of its capacity before recharging.

Temperature also plays a crucial role in determining the cycle life of a battery. High temperatures accelerate the chemical reactions occurring within the battery, which can lead to increased degradation of the battery's electrodes and electrolyte. As a result, batteries operated at elevated temperatures often have shorter cycle lives compared to those operated at lower temperatures.

The charging and discharging rates of a battery can also impact its cycle life. Rapid charging and discharging rates generate more heat and stress on the battery, potentially reducing its cycle life. Conversely, slower charging and discharging rates are generally less demanding on the battery and can contribute to a longer cycle life.

2.4.3 Memory Effect

The memory effect is a phenomenon that can occur in certain battery chemistries, particularly nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries. It refers to a situation where a battery "remembers" the previous charge and discharge cycles, leading to a reduction in its overall capacity over time. This effect is most prominent when batteries are repeatedly charged and discharged to the same level [15].

In batteries susceptible to the memory effect, if they are consistently discharged to a shallow depth of discharge (DoD) or partially charged, the battery "learns" to adapt to this specific usage pattern. As a result, the battery may exhibit a reduced capacity, seemingly "remembering" the limited range of the previous charge and discharge cycles.

However, it's important to note that the memory effect is less prevalent in lithium-ion (Li-ion) and lithium polymer (LiPo) batteries compared to NiCd and NiMH batteries. This is due to the differences in their underlying chemistry and the absence of certain memory effect mechanisms in Li-ion and LiPo batteries [15].

Lithium-ion and lithium polymer batteries are known for their improved performance and reduced susceptibility to the memory effect. These batteries have different internal structures and chemistries that allow them to be charged and discharged more flexibly without significant capacity loss. While they are not completely immune to capacity degradation over time, proper battery management practices such as avoiding deep discharge and overcharging can help mitigate any potential capacity loss and ensure their longevity [15].

Therefore, when considering battery options for remote control cars, it is advantageous to choose lithium-ion or lithium polymer batteries over nickel-based batteries (NiCd and NiMH) to minimize the impact of the memory effect and maintain optimal performance throughout the battery's lifespan.

2.4.4 Safety

NiCd and NiMH batteries are relatively safe, but they can experience thermal runaway if overcharged or damaged, which can lead to venting, leakage, and potentially hazardous conditions. Li-ion and LiPo batteries are generally considered to be safer than NiCd and NiMH batteries, thanks to their improved design and built-in safety features such as protection circuits that prevent overcharging, over-discharging, and short-circuiting. However, like any battery, Li-ion and LiPo batteries can still be dangerous if mishandled, damaged, or misused[25]

2.5 Battery Monitoring system

Battery monitoring systems are essential for ensuring optimal performance and safety in remote control cars, as these vehicles rely solely on batteries for operation. These systems enable real-time monitoring and management of critical battery parameters such as voltage, current, temperature, and state of charge. By collecting and analyzing this data, users gain valuable insights into the battery's health and performance, enabling informed decisions regarding charging, maintenance, and replacement. Literature review studies in the field of electric vehicles have highlighted the significance of battery management systems in enhancing battery performance and safety. They have explored the development of monitoring systems and their impact on battery performance, offering insights into advancements and challenges. Additionally, specific studies on battery management systems for electric remote control cars have proposed hardware and software solutions for real-time monitoring and protective measures against issues like overcharging and overheating. By conducting a thorough literature review, this project gains a comprehensive understanding of battery monitoring principles, technologies, and challenges, facilitating informed decision-making and potential areas for improvement. Ultimately, implementing an effective battery monitoring system in remote control cars enhances performance, prolongs battery life, and ensures safety.

2.5.1 Voltage of Battery

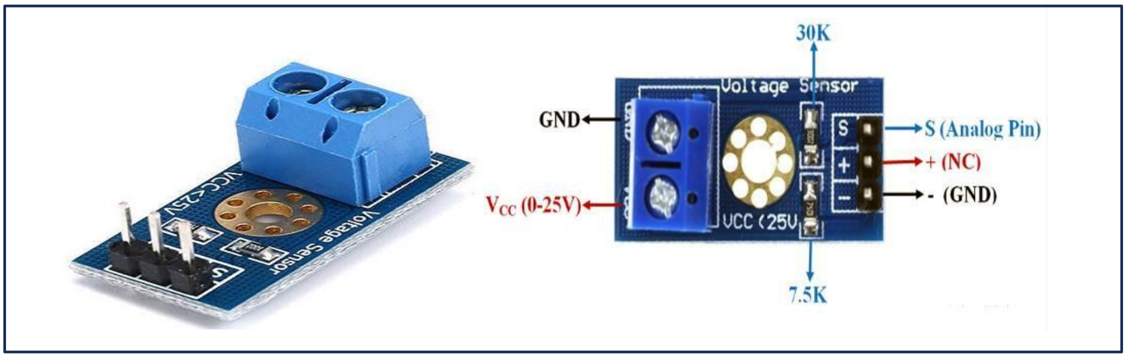


Figure 7: Voltage Sensor

In remote control cars, the voltage of the battery plays a vital role in determining the device's performance and safety. Monitoring the battery voltage in real-time is crucial for optimizing battery performance, extending battery life, and preventing potential hazards like overcharging or overheating [38]. The voltage of a battery is influenced by the chemical reactions occurring inside it, decreasing as the battery discharges and increasing during the charging process. Additionally, temperature and load can also affect the voltage, with high temperatures and heavy loads leading to voltage drops [39].

To monitor battery voltage in remote control cars, sensors are commonly used to measure the battery's terminal voltage. This data is then transmitted to a monitoring system, which analyzes it and provides users with insights regarding the battery's performance and health. A relevant study [21] focused on developing a real-time monitoring system for electric vehicles, utilizing wireless communication to transmit battery voltage data to a central monitoring system. This system offers users valuable information about the battery's state of charge, health, and performance.

In summary, monitoring battery voltage is crucial for enhancing battery life and ensuring safety in remote control cars. Real-time monitoring enables optimized battery performance, prolonged battery life, and the prevention of potential hazards. Literature review studies have demonstrated that battery voltage monitoring systems provide valuable insights into battery health and performance, facilitating optimized battery charging, maintenance, and replacement strategies. Therefore, battery voltage monitoring is an indispensable component of any battery monitoring system designed for remote control cars [40].

2.5.2 Current Sensor

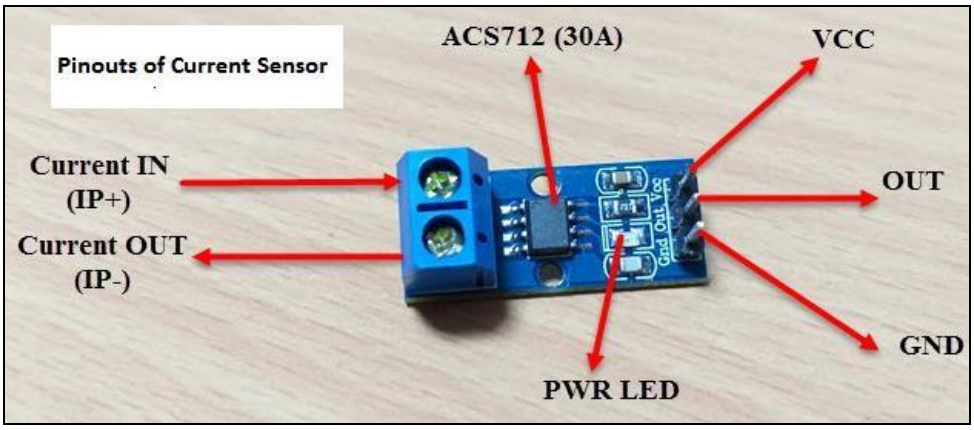


Figure 8 : Current Sensor

Current sensors are essential components of battery monitoring systems, especially in remote control cars. A current sensor measures the current flowing through a circuit and provides real-time data on the battery's performance and health. Current sensors are critical in identifying abnormal current behavior, such as overcurrent or undercurrent, which can lead to hazardous situations, such as overheating or battery damage[6]

In remote control cars, current sensors are typically placed in series with the battery to measure the current flowing to the motor. The data is then transmitted to a monitoring system that analyzes the data and provides users with insights into the battery's performance and health.

Many studies have been conducted on current sensors and their impact on battery performance and safety. One study by R. Shen et al. (2020) proposed a battery monitoring system for electric vehicles that uses a combination of current sensors and voltage sensors to monitor the battery's performance. The study showed that the combination of current and voltage sensors can provide valuable insights into the battery's state of charge, health, and performance[24]

In conclusion, current sensors are essential components of battery monitoring systems in remote control cars. Real-time monitoring of the battery's current can help identify abnormal current behavior, such as overcurrent or undercurrent, and prevent hazardous situations. Literature review studies have shown that current sensors can provide valuable insights into the battery's performance and health. As such, current sensors are an essential component of any battery monitoring system for remote control cars[38]

2.5.3 Temperature Sensor

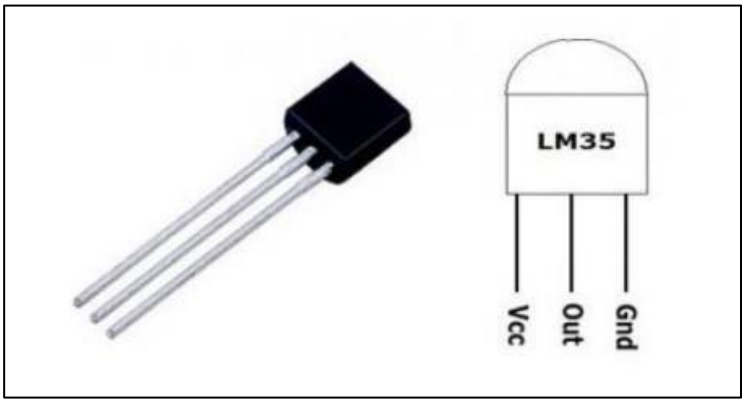


Figure 9 : LM35 Temperature Sensor with pinout

Temperature sensors are an essential component of battery monitoring systems, particularly in remote control cars. They measure the temperature of the battery and provide real-time data on the battery's health and performance. Temperature sensors are critical in identifying abnormal temperature behavior, such as overheating or overcooling, which can lead to hazardous situations, such as battery damage or failure.[39]

In remote control cars, temperature sensors are typically placed on the battery or in the battery compartment to measure the temperature of the battery during operation. The data is then transmitted to a monitoring system that analyzes the data and provides users with insights into the battery's performance and health.[40]

Many studies have been conducted on temperature sensors and their impact on battery performance and safety. One study by K. Dong et al. (2019) proposed a battery monitoring system for electric vehicles that uses temperature sensors to monitor the battery's temperature. The study showed that the temperature sensors can provide valuable insights into the battery's health and performance.[41]

Another study by Y. Huang et al. (2018) proposed a temperature sensor based on the thermistor for battery monitoring systems. The study showed that the thermistor-based temperature sensor is accurate and reliable in measuring the temperature of the battery.

In conclusion, temperature sensors are essential components of battery monitoring systems in remote control cars. Real-time monitoring of the battery's temperature can help identify abnormal temperature behavior and prevent hazardous situations. Literature review studies have shown that temperature sensors can provide valuable insights into the battery's performance and health. As such, temperature sensors are an essential component of any battery monitoring system for remote control cars.

2.5.4 Arduino Nano 3.0 Compatible ATMEGA328P

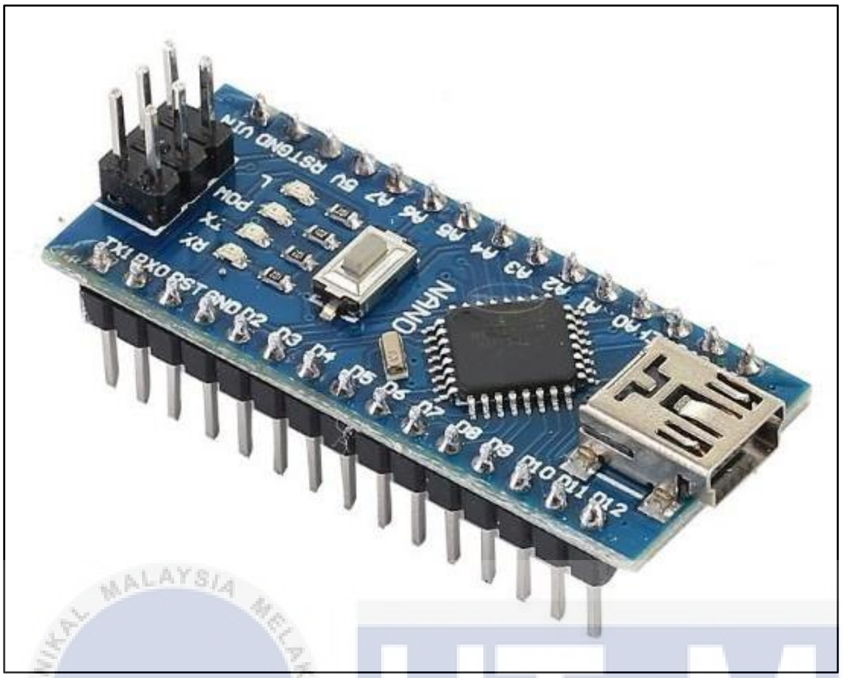


Figure 10 : Arduino Nano 3.0 Compatible ATMEGA328P

The Arduino Nano 3.0 as shown in Figure 10, powered by the ATmega328P microcontroller, is a highly versatile and compact development board designed for various embedded projects, including IoT applications. Its compatibility with the ATmega328P microcontroller ensures robust performance and straightforward programming, making it a preferred choice for diverse electronic systems. In the context of the battery monitoring system developed for remote control cars, the Arduino Nano 3.0 likely served as the system's core control unit.

This board is well-suited for managing sensor inputs, processing data, and communicating wirelessly, which aligns perfectly with the requirements of a real-time battery monitoring system. Its small form factor allows for seamless integration within the monitoring setup, contributing to the system's efficiency and compact design. The built-in USB connectivity simplifies the programming process, enabling easy interfacing with sensors like voltage and temperature sensors, and facilitating the transmission of critical battery health information to a central monitoring unit.

In summary, the Arduino Nano 3.0, with its ATmega328P microcontroller, serves as the brain of the battery monitoring system, enabling it to collect, process, and transmit real-time battery health data. Its reliability, compact size, and compatibility make it a suitable choice for integrating with various sensors and components crucial for effective battery monitoring in remote control cars.

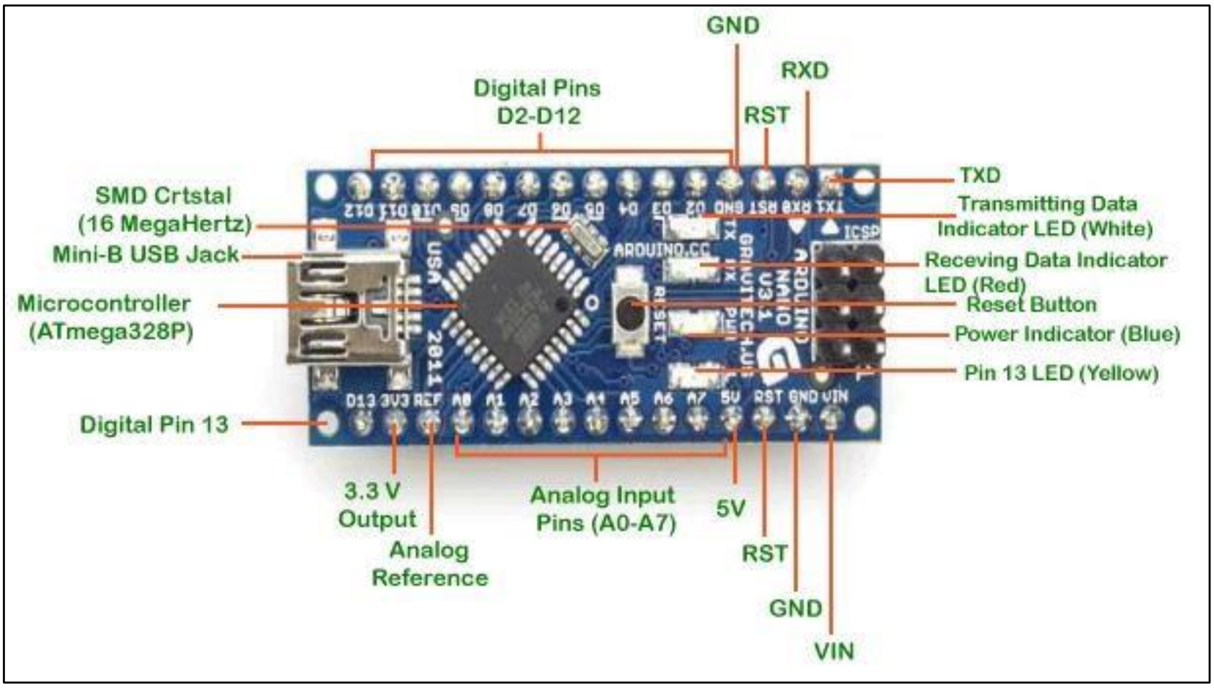


Figure 11 : Arduino Nano Pinout

1. **RXD and TXD**: These pins, often referred to as RX (receive) and TX (transmit), are used for serial communication. RXD is the receive pin, used for receiving data, while TXD is the transmit pin, used for sending data.

2. **Mini USB**: The Mini USB port allows for connecting the Arduino Nano to a computer or power source for programming, power supply, or data transfer.

3. **SMD Crystal**: The Surface Mount Device (SMD) Crystal provides the clock signal to the microcontroller. It helps regulate the timing of operations, ensuring that the microcontroller functions at the correct speed.

4. **RST**: The Reset pin allows you to restart the microcontroller. When this pin is momentarily connected to GND, it triggers a reset, restarting the code execution from the beginning.

5. **Power Indicator**: This LED indicator lights up when the Arduino Nano is powered, providing a visual cue that the board is receiving power.

6. **Digital Pins**: These pins (D2 - D13) can be configured as digital inputs or outputs. They are capable of reading digital signals (input) or outputting digital signals to control various components (output).

7. **Analog Pins**: The analog pins (A0 - A7) can read analog voltages, such as those from sensors or other analog devices. Additionally, on later Nano models, A6 and A7 can also be used as digital pins.

8. **Analog Reference (AREF)**: The Analog Reference pin allows for setting the reference voltage for analog inputs. By default, the reference voltage is set to the operating voltage (5V or 3.3V).

9. **Vin**: The Vin pin allows you to supply voltage to the board. It can be connected to an external power source to power the Arduino Nano.

10. **3.3V and 5V**: These pins provide regulated power output. The 3.3V pin outputs 3.3 volts, while the 5V pin outputs 5 volts. They can be used to power external sensors or modules requiring specific voltage levels.

2.6 Monitoring system with microcontroller

Based on the article I read, by [45] claims that microcontroller advancement has attracted many researchers all over world. This is due to performance and effectiveness of daily use in different kind of application such as wireless system, automation industry and medical use. The higher demand of the industry player in various application fulfilled. With the using of microcontroller, monitoring and estimatin can apply to increase user effective and reduce charge of specific task.

Monitoring system with microcontroller because of single-chip purpose computerized can be useful in many applications. This is due to microcontroller contain random access memory (RAM), readonly memory (ROM), flash memory, input and output peripheral and processing unit. Anyhow, microcontroller performance cannot compete with desktop processor unit. But still microcontroller use all over world for various application.

Based on the article I read [46] describe that today's electrical appliance and also gadgets are equip with microprocessor and microcontroller such as mobile phone and television. The electrical appliance not only applied with microcontroller, the features of electrical appliance control by microcontroller. For today's world, microcontroller plays important role in IT industry and semiconductor. Microcontroller in embedded system has develop drastically in industrial.

2.6.1 ESP-32 Mirocontroller

The ESP32 microcontroller is a highly capable and versatile device that is well-suited for creating IoT-based monitoring and control systems. It finds applications in various fields like home automation, wearable devices, and smart appliances, thanks to its impressive processing power, energy efficiency, and built-in Wi-Fi and Bluetooth capabilities.

Utilizing the ESP32 microcontroller, we can significantly improve the battery life and safety of remote control cars through real-time IoT monitoring. By connecting the ESP32 to the car's battery and other sensors, we can monitor critical parameters such as performance and environmental conditions (e.g., temperature, humidity, and motion) in real-time. This collected data can then be wirelessly transmitted to a cloud-based platform, where it can be analyzed to optimize battery usage and ensure safety measures are in place.[47]

In summary, the ESP32 microcontroller serves as a robust and adaptable platform for developing IoT-based monitoring and control systems, making it an excellent choice for our project focused on enhancing battery life and safety in remote control cars through real-time IoT monitoring. Figure 11 shows the ESP-32 Microcontroller picture below,

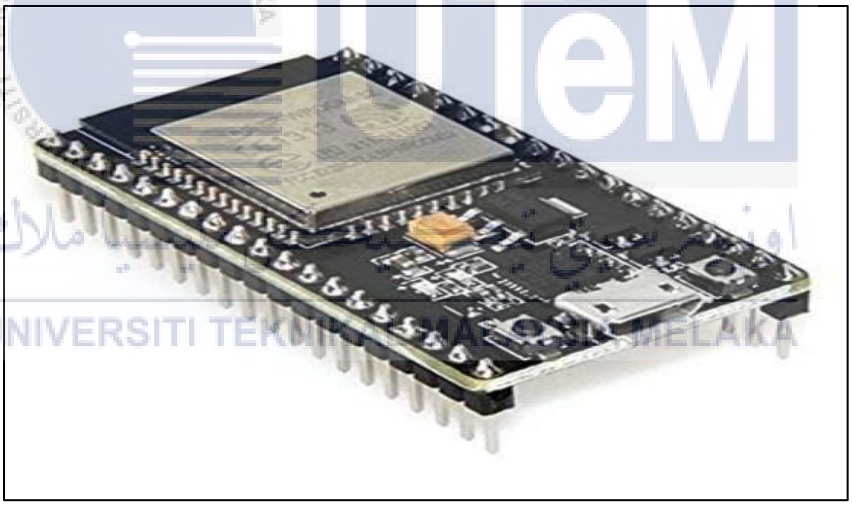


Figure 12 : ESP-32 Microcontroller

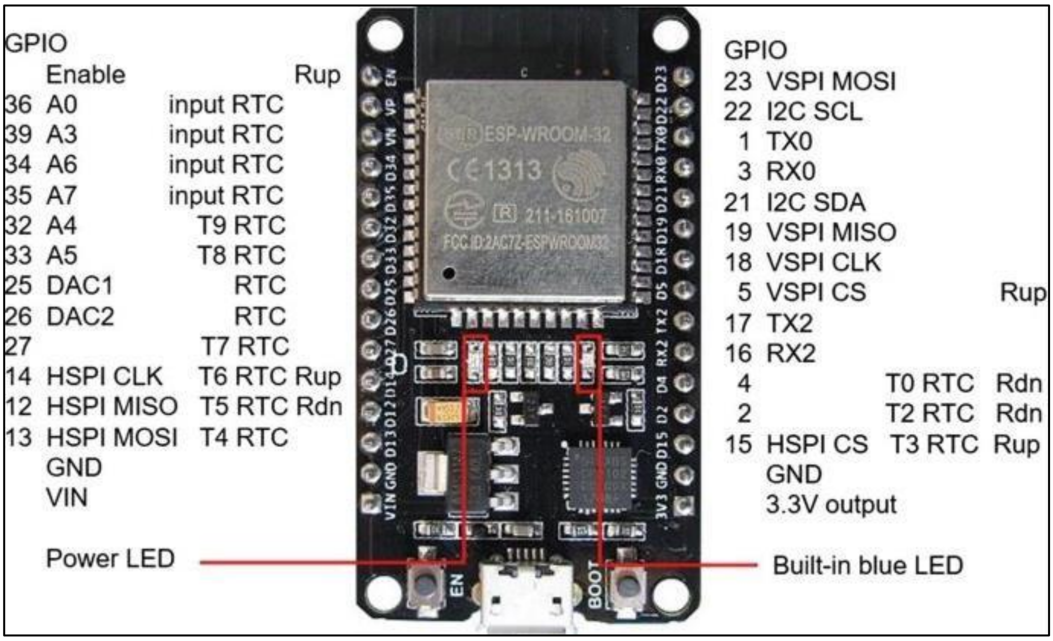


Figure 13 : ESP-32 Microcontroller Features[46]

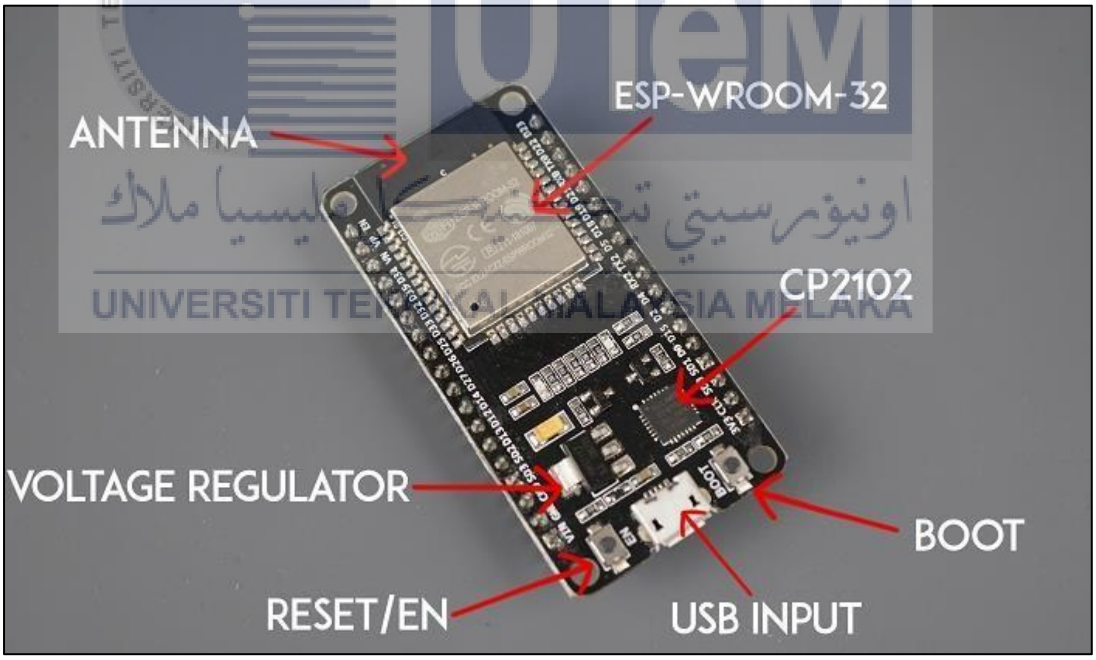


Figure 14 : ESP-32 Microcontroller Parts and Buttons[48]

2.7 NANO 5V I/O Sensor Servo Expansion Prototype Shield V3.0 for Arduino

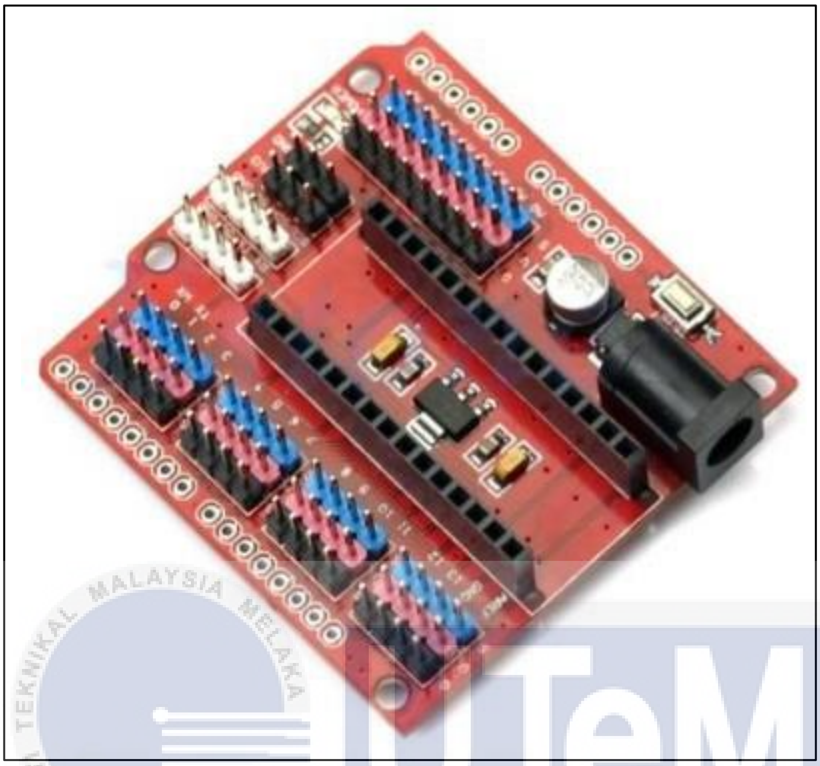


Figure 15 : NANO 5V I/O Sensor Servo Expansion Prototype Shield V3.0 for Arduino

The Nano 5V I/O Sensor Servo Expansion Prototype Shield V3.0 for Arduino acts as a supplementary board compatible with the Arduino Nano, enabling streamlined connectivity for a myriad of components and sensors. Specifically designed to be paired with the Arduino Nano, it offers an organized platform to seamlessly integrate various components, expanding the project's functionalities.

2.7.1 Key features of the shield include:

1. Arduino Nano Compatibility: Tailored to perfectly fit the Arduino Nano, facilitating hassle-free attachment and integration.

2. Stable 5V Power Supply: Equipped with a regulated 5V power supply, ensuring consistent power distribution across connected peripherals.

3. Versatile I/O Pins: Provides multiple accessible I/O pins for effortless connections to diverse sensors, modules, and actuators, amplifying the project's capabilities.

4. Sensor Adaptability: Designed to accommodate an array of sensors like temperature sensors, motion sensors, and light sensors, enhancing the project's adaptability.

5. Support for Servo Motors: Includes dedicated connectors or pins for servo motors, simplifying their control and operation without additional wiring complexities.

6. Prototyping Zone: Some versions feature a prototyping area with standardized spaced through-holes, allowing for additional electronic components or circuitry integration that may not be directly supported.

7. Enhanced Project Scope: Enables seamless expansion of the Arduino Nano's capabilities, catering to a broad spectrum of applications such as robotics, automation, and sensor-driven projects.

8. This shield streamlines the integration process for a wide range of components and sensors, facilitating their seamless interaction with the Arduino Nano. Its utility lies in simplifying the connections and enabling diverse components to collaborate effectively within the project.

2.8 LCD 1602 (2x16) Basic Character Display LCD1602

Figure 16 : LCD 1602 (2x16) Basic Character Display LCD1602

The LCD 1602 (2x16) Basic Character Display, often referenced as the LCD1602, is a fundamental and widely used alphanumeric display module compatible with Arduino boards, including the Arduino Nano. This component serves as a visual interface, capable of showcasing text-based information across two rows with 16 characters each.

2.8.1 Key features of the LCD1602 include

1. Size and Format: The display consists of two rows, each capable of showcasing up to 16 characters. This format provides concise yet adequate space for displaying essential project-related information.

2. Alphanumeric Display: Capable of displaying both letters and numbers, making it suitable for showcasing critical data, sensor readings, system statuses, or user prompts.

3. Backlight Functionality: Some models offer backlight support, enhancing visibility in various lighting conditions. The backlight can often be controlled, allowing customization based on project requirements.

4. Parallel Interface: Typically operates through a parallel interface, simplifying connectivity to microcontrollers like the Arduino Nano.

5. Simple Control: Controlled through a relatively straightforward interface, requiring a minimal number of connections to the Arduino board.

6. Project Integration: Provides an intuitive means to showcase real-time data, status messages, or prompts, contributing to user interaction and system feedback in the project.

7. The LCD1602 serves as a reliable and straightforward display module, allowing users to present critical project data or system information in a clear and easily accessible format. Its compatibility with Arduino boards makes it a popular choice for various projects that require real-time visual feedback or status updates.

2.9 DC Gear TT Motor for Arduino

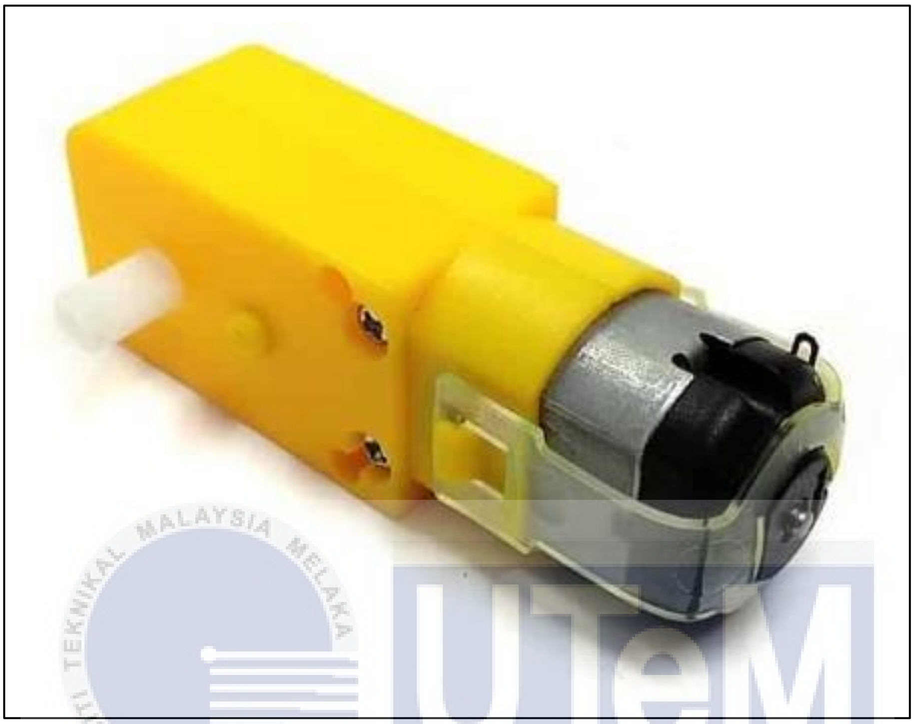


Figure 17 : Dc Gear Tt Motor For Arduino

The DC Gear TT Motor, often integrated into Arduino projects, stands out for its adaptability, efficiency, and ease of control. These motors come in various sizes, offering different torque ratings that cater to diverse applications while maintaining a compact and lightweight design suitable for smaller projects or those demanding moderate torque. Their flexibility in speed control via pulse width modulation (PWM) allows for precise adjustments, ensuring optimal speed alignment with project requisites. Bidirectional operation, facilitated by straightforward Arduino programming, enables both clockwise and counterclockwise rotations, adding versatility to applications. Their compatibility with Arduino and other microcontrollers makes them a preferred choice in robotics, automation, or projects needing controlled motion. They play pivotal roles in powering moving parts or mechanisms within various projects, contributing to their reliable functionality. Additionally, these motors prioritize power efficiency, functioning with low power consumption, making them a favorable choice for battery-powered projects or those requiring energy-efficient components.

2.10 Switch ON/OFF

Figure 18 : Switch On/Off

The KCD1 ON/OFF Round Rocker Toggle Switch is a fundamental electrical component widely used in circuits and projects requiring manual control. Key features include:

1. Functionality: It serves as a simple ON/OFF switch, allowing users to control the flow of electricity in a circuit by toggling between the two positions.

2. Versatility: Known for its versatility, this switch is compatible with a wide range of applications, from basic electronics projects to more complex electrical systems.

3. Durability: Designed for durability and longevity, it can withstand frequent use and various environmental conditions, ensuring reliable performance over time.

4. Ease of Use: Its straightforward design and user-friendly functionality make it accessible for beginners and experienced users alike, serving as a convenient interface for circuit control.

5. Application: Widely employed in DIY electronics, electrical appliances, automotive applications, and various electrical projects that require manual on/off control.

6. These switches are known for their reliability, ease of installation, and essential role in providing manual control within electrical systems and circuits.

2.11 Adapter 12v

Figure 19 : Power Adapter 12v

The AC to DC 12V 2A UK Power Adapter is a crucial electrical device converting alternating current (AC) to direct current (DC) at 12 volts and providing a maximum output current of 2 amperes. Key attributes include:

1. Voltage Conversion: It converts the standard household alternating current (AC) power supply to a direct current (DC) output of 12 volts, making it suitable for various electronics and appliances that require this voltage.

2. Amperage Capacity: With a maximum output current of 2 amperes, it can power devices or systems that require up to 2A of current at 12V, ensuring compatibility with a wide range of equipment.

3. Plug Type: Designed for the UK, the adapter features a plug compatible with standard UK power outlets, making it convenient for use in that region.

4. Versatility: Widely used for powering LED strips, routers, CCTV cameras, certain types of electronics, and other devices that operate on a 12V DC power supply.

5. Reliability: Known for its stable and consistent power output, offering reliable performance and protection against power fluctuations.

6. Compatibility: Its 12V DC output and 2A current capacity make it compatible with various electronics, providing a standard power solution for devices requiring this specific voltage and current.

This adapter serves as a reliable power source, converting household AC power to a suitable 12V DC output, ensuring compatibility and stable performance for a variety of electronics and appliances.

2.12 Blynk App

Figure 20 : Blynk App Logo

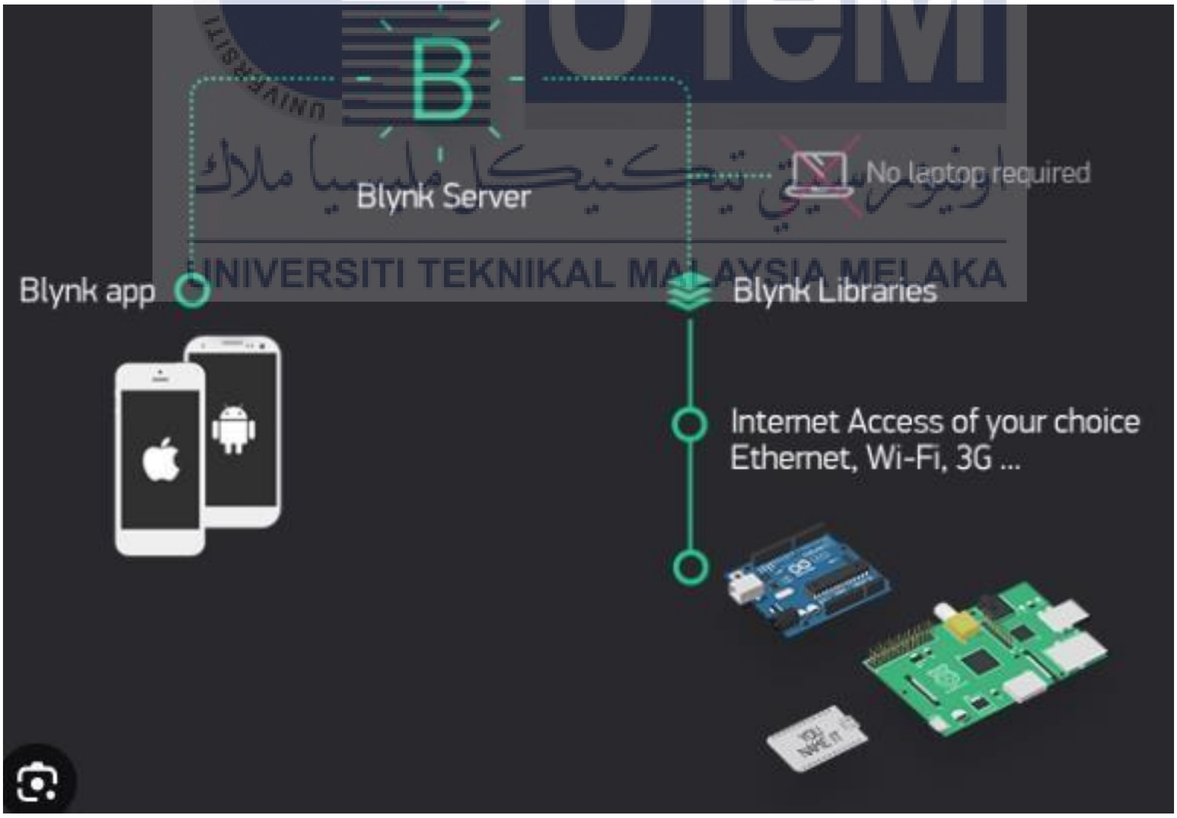


Figure 21 : Blynk App Process Flow

The Blynk app is an intuitive and user-friendly platform designed for IoT (Internet of Things) projects, allowing users to create custom interfaces to control and monitor connected devices remotely. Key features of the Blynk app include:

1. Interface Customization: Users can design their own interfaces or dashboards using a drag-and-drop interface builder, enabling control buttons, sliders, gauges, graphs, and other widgets to visualize and interact with connected devices.

2. Device Connectivity: The app supports various microcontrollers like Arduino, Raspberry Pi, ESP8266, and others, facilitating easy integration with a wide range of IoT hardware.

3. Cloud Connectivity: Blynk provides cloud connectivity, allowing users to remotely access and control their connected devices from anywhere with an internet connection.

4. API Integration: It offers APIs for developers to create custom functions and integrations, enhancing the functionality and versatility of the app.

5. Notifications and Alerts: Users can set up notifications and alerts triggered by specific events or conditions, enabling real-time updates and warnings about connected devices.

6. Energy Efficiency: Blynk operates on an energy-based model, requiring energy points for each widget used on the interface, offering flexibility in usage and cost-effectiveness.

7. Community and Sharing: It fosters a community where users can share their projects, ideas, and code snippets, facilitating collaboration and learning among IoT enthusiasts.

Overall, the Blynk app serves as a powerful tool for IoT enthusiasts and developers, providing a user-friendly interface to create, control, and monitor IoT projects seamlessly from a mobile device.

The selection of the Blynk app for integrating with the battery monitoring system stems from its robust features and adaptability within the IoT ecosystem. In the context of IoT applications for battery monitoring, the Blynk app stood out due to several key factors.

Firstly, its user-friendly interface and customizable dashboard creation capabilities allow for a tailored visualization of critical battery parameters. This feature is pivotal as it facilitates the display of real-time data concerning battery health, such as voltage, current, and temperature, empowering users to monitor their batteries effectively. Moreover, Blynk's cloud connectivity offers the flexibility of remote access and control. This is crucial for battery monitoring systems integrated into remote control cars, allowing users to receive notifications and alerts even when they are not in close proximity to their vehicles. The app's ability to deliver real-time notifications based on predefined thresholds or critical battery conditions adds an essential layer of safety and proactive monitoring.

Furthermore, Blynk's compatibility with various microcontrollers and its comprehensive API support made it an optimal choice for seamless integration with the battery monitoring system. Its versatility enables the system to transmit data wirelessly to the app, ensuring that users have access to pertinent battery information at their fingertips. The Blynk app's energy-efficient model aligns with the project's aim to optimize power consumption, which is crucial for IoT devices running on batteries. Its robust community support also offers an avenue for sharing insights and troubleshooting, enhancing the project's development process. In essence, the Blynk app was chosen for its versatility, user-friendly interface, cloud-based connectivity, and compatibility with IoT hardware. These features collectively make it an ideal platform for the successful implementation of the battery monitoring system, enabling effective real-time monitoring and notifications for users, especially in the context of remote control car applications.

2.13 PVC Project Box

Figure 22 : Pvc Project Box

The Waterproof Plastic Electronic Project Box Enclosure Case is an essential protective housing for electronic circuits, offering durability and shielding against moisture, dust, and external elements. Its sturdy, waterproof plastic construction ensures longevity and reliability for both indoor and outdoor applications. This versatile enclosure accommodates various circuit configurations, facilitating easy customization with drillable surfaces for switches, connectors, and interfaces. With a secure locking mechanism and provisions for wall mounting, it provides a tight seal, preventing water ingress and debris. Overall, it serves as a crucial component, safeguarding delicate electronics in challenging environments.

1. Durability and Protection: Constructed from sturdy and waterproof plastic, this enclosure shields electronic components from moisture, dust, and other external elements, ensuring the longevity and reliability of the circuitry within.

2. Versatile Design: The box's design allows for flexibility in accommodating various circuit configurations, offering ample space for components, connectors, and wiring, while its waterproof nature makes it suitable for both indoor and outdoor applications.

3. Easy Customization: With its plastic construction, the enclosure is easily modifiable, enabling the drilling of holes for switches, connectors, and interfaces, facilitating seamless integration of the project's components while maintaining its waterproof integrity.

4. Secure Closure Mechanism: Equipped with a secure locking mechanism, typically via screws or clasps, this enclosure ensures a tight seal, preventing ingress of water or debris, which is vital for projects in challenging or exposed environments.

5. Mounting Options: The design often includes provisions for wall mounting or attaching to other structures, adding convenience in installation and positioning of the project box.

Overall, the Waterproof Plastic Electronic Project Box Enclosure Case provides an essential protective housing, safeguarding delicate electronic components from environmental hazards, making it an indispensable component for projects that require durability and environmental resistance.

2.14 Remote Control Car

Remote control cars, commonly referred to as RC cars, are miniature model cars that can be controlled remotely using a wireless transmitter and receiver. These cars are popular among children and hobbyists, offering a range of designs, sizes, and features. The fundamental components of an RC car include the chassis, wheels, and motor, all operated through a handheld transmitter[52].

Over time, RC cars have evolved to include advanced functionalities like multiple speed settings, shock absorbers, and LED lights. Additionally, some models are designed to tackle diverse terrains such as dirt, sand, or water.

Recent advancements have witnessed the integration of RC cars into Internet of Things (IoT) systems, enabling users to remotely monitor and control performance and safety aspects. This involves the addition of sensors to measure battery life, temperature, and other key metrics, with data transmission to an IoT monitoring system for analysis and optimization[53].

In the project focused on enhancing battery life and safety in remote control cars through real-time IoT monitoring, an exploration of RC car types, their suitability for IoT integration, and the selection of appropriate sensors, components, wireless connectivity protocols, and safety features will be undertaken. Figure 14 illustrates a representative image of a remote control car.

Figure 23 : Remote Control Car[54]

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will describe the methodology used in this project to enhance the battery life and safety in remote control cars through a real-time IoT monitoring system. The methodology is the framework that outlines the steps and procedures that will be taken to achieve the research objectives. This chapter will provide an overview of the research design, data collection methods, data analysis techniques, and IoT Integration used in the project.

3.2 FLOWCHART

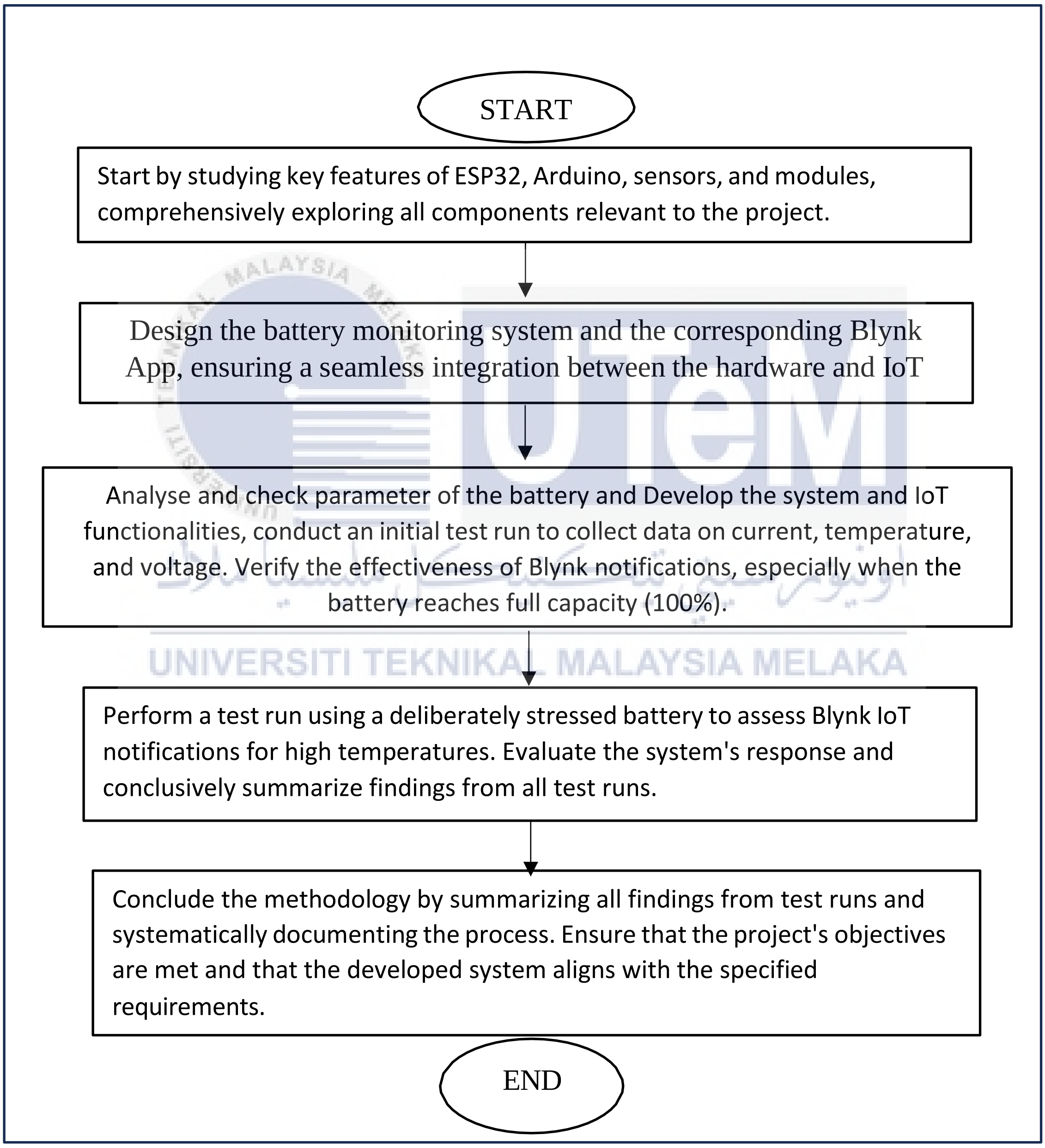


Figure 24 : Methodology FlowChart

3.2.1 Analyzing and Checking Parameters of the Lithium-ion (Li-ion) Battery

1. Conduct a comprehensive analysis of the key parameters of the Li-ion battery used in remote control cars, including voltage, current, temperature, and capacity.
2. Research and reference industry standards and guidelines for Li-ion battery parameter analysis in similar applications.

3.2.2 Studying the Key Features of ESP-32 Microcontroller, Sensors, and Modules

1. Perform an in-depth study of the ESP-32 microcontroller, including its capabilities, features, and compatibility with battery monitoring applications.
2. Research and evaluate various sensors and modules suitable for measuring battery parameters such as voltage, current, and temperature.

3.2.3 Developing the Remote Car and Designing the Circuit with the Lithium-ion Battery

1. Design and assemble the remote control car, considering factors such as size, weight, and power requirements.
2. Implement safety measures to prevent overcharging, over-discharging, and short-circuiting of the battery.

3.2.4 Designing the Battery Monitoring System with Data Measurement

1. Develop the circuitry and connections necessary to measure battery parameters, such as voltage, current, and temperature.
2. Determine the appropriate sensor placements and wiring configurations to ensure accurate and reliable data measurement.
3. Implement signal conditioning and amplification techniques to enhance the accuracy and stability of the measured data.

3.3 Good Battery Working Style Flowchart:

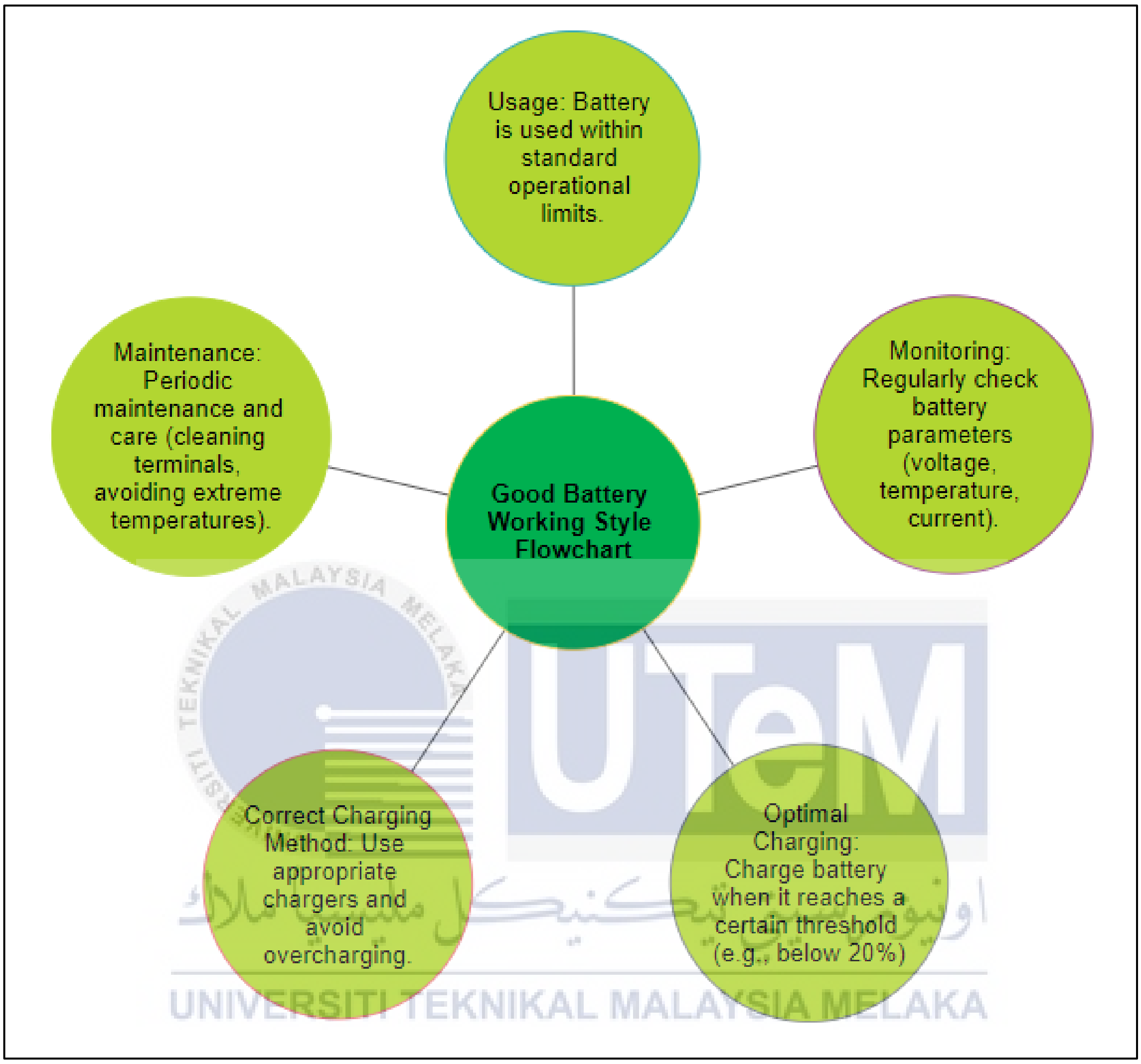


Figure 25 : Good Battery Working Style

The outlined flowchart delineates a systematic approach towards maintaining a battery in an optimal state. It commences with the initial step of ensuring a charged battery, followed by adhering to standard operational usage limits. Regular monitoring of critical battery parameters, encompassing voltage, temperature, and current, is emphasized to ensure proactive assessment of its health. Optimal charging practices, triggered when the battery nears a predefined threshold (e.g., below 20%), coupled with utilizing appropriate chargers to prevent overcharging, form crucial steps. Maintaining the battery within optimal temperature ranges and employing efficient usage practices—avoiding excessive or prolonged strain—further contribute to its longevity. Lastly, periodic maintenance routines, encompassing terminal cleaning and avoiding extreme temperature exposures, are pivotal in ensuring sustained battery performance. This systematic approach culminates in a battery that not only endures but also operates optimally, thereby enhancing its overall longevity and efficiency.

3.4 Bad Battery Working Style Flowchart

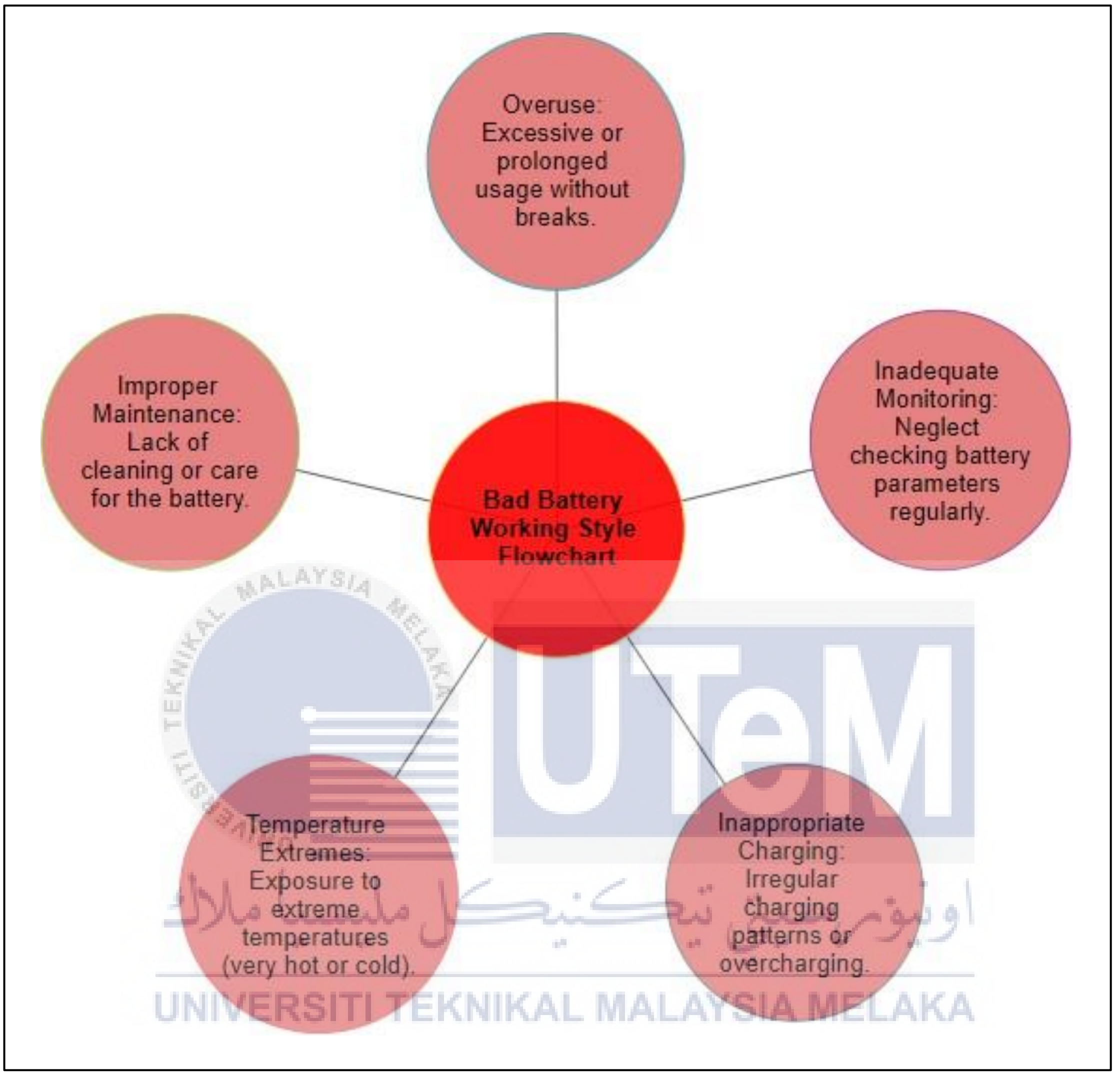


Figure 26 : Bad Battery Working Style

The delineated flowchart outlines a sequence of practices that contribute to a battery's suboptimal functionality and potential deterioration. Commencing with a charged battery, the detrimental path unfolds with excessive or prolonged usage without intervals, exerting undue strain on the battery. Neglecting regular checks on essential battery parameters further exacerbates this degradation, leading to inadequate monitoring. Irregular charging patterns or overcharging, coupled with exposure to extreme temperature conditions, be it excessively hot or cold, compound the battery's deteriorating state. Additionally, improper maintenance, characterized by neglecting cleaning or care routines, accelerates the battery's decline. Collectively, these adverse practices culminate in the battery's degradation, resulting in a diminished lifespan or potential safety hazards, highlighting the critical importance of adhering to proper battery management practices to ensure optimal functionality and longevity.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter explores the outcomes of developing a real-time IoT battery monitoring system for remote control cars. It includes practical evidence gathered during the project, linking theory with real results. We thoroughly examined the system's performance through strict tests and real-world use.This chapter encapsulates the empirical evidence and insights gained throughout the project's lifecycle. It serves as the nexus where theory meets practice, and where ideas transform into tangible results.The journey through this chapter will take us through a comprehensive exploration of the performance and capabilities of our innovative monitoring system. The journey within these pages involves a systematic analysis of empirical data, aimed at revealing the system's true potential and the consequential implications it bears. While direct user feedback was not a component, the project derived insights from robust testing methodologies and real-world application scenarios, shaping its functional efficacy.

Additionally, the testing and integration of the Blynk app into the system were crucial milestones, offering insights into the system's practicality and usability. By systematically dissecting the results, we aim to unveil the true potential and practical implications of our technology.Beyond the numerical findings, our discussion delves into the broader context, also analyze how this project aligns with the initial objectives, the significance of the outcomes, and the practical implications for the field of remote control car technology. Moreover, we engage in a candid discussion of the project's limitations.

The "Results and Discussion" chapter serves as a testament to our dedication, the innovative spirit that fueled this project, and the potential it holds to revolutionize the remote control car industry. It is a manifestation of our quest to empower enthusiasts, enhance safety, and extend the life of the batteries powering their passion. This chapter stands as a testament to relentless dedication, showcasing the innovative drive that propelled this project. It illuminates the potential to redefine and revolutionize the remote control car industry, heralding an era focused on enhancing safety and extending battery life.

4.1 Originality of the RC Battery Charger

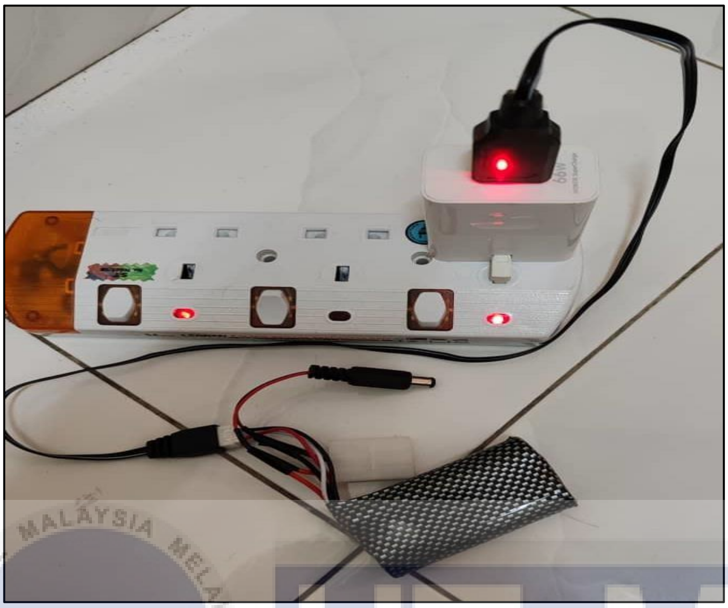


Figure 27 : Picture Of Red Led Light (Charging)

Figure 28 : Picture Of Green Led Light (Battery Full)

The breakdown in Table 2.0 below offers a comprehensive overview of the battery charging system, highlighting both its positive attributes and notable limitations. It showcases the system's effectiveness in communicating the charging status through the red LED indicator, providing users with a clear and easily understandable visual cue during the charging process. However, discernible drawbacks arise from the absence of fundamental sensors—temperature, current, and voltage sensors. The lack of a temperature sensor poses a significant safety concern, impeding the system's ability to monitor potential temperature fluctuations during charging, jeopardizing battery integrity and safety. Similarly, the omission of a current sensor limits the system's regulation of input current from the adapter, potentially compromising charging efficiency and safety measures. Additionally, the absence of a voltage sensor impedes the monitoring of the battery's voltage percentage, a pivotal factor in preventing overcharging that could substantially impact battery lifespan and safety. Moreover, the original charger's failure to display essential battery status information, like charging activity or full charge, creates usability challenges, hindering users from informed battery management.

As illustrated in Table 2.0 below, the breakdown succinctly presents the system's characteristics and limitations for a clearer understanding.

Table 3 : Characteristics and Limitations of the Battery Charging System

Feature	**Description**
Charging Status	The red LED indicates the battery is charging, a common visual cue for the charging phase.
Simplicity	Utilizing a single LED for charging status offers intuitive understanding (Red = Charging).
Temperature Sensor	Absence of a temperature sensor for detecting battery temperature during charging.
Current Sensor	Lack of a sensor to monitor the battery's current input from the adapter.
Voltage Sensor	No sensor to measure the battery's voltage percentage (0 to 100%) to prevent overcharging.
Battery Status	Original charger doesn't display battery status (e.g., Charging / Battery Full).

4.2 Battery Health Monitoring System (Developed Charger)

Figure 29 : Battery Health Monitoring System Show The Parameters Of The Battery Such As (Voltage,Temperature,Current And The Indicator When Battery Full)

The breakdown in Table 3.0 delineates the characteristics of the battery charging system, emphasizing its features and areas of functionality. Notably, the system effectively utilizes LED indicators to communicate charging status, employing a single LED for simplicity. A lack of the Green LED signifies ongoing charging, while its illumination signals a fully charged battery at 100% voltage. Moreover, the inclusion of crucial sensors—temperature, current, and voltage sensors—enhances the system's functionality. The presence of a temperature sensor allows monitoring of the battery's temperature during charging, ensuring safety. Similarly, the current sensor tracks the battery's input from the adapter, optimizing charging efficiency. Additionally, the voltage sensor plays a vital role in preventing overcharging by monitoring the battery's voltage percentage. Furthermore, the Battery Health Monitoring System provides real-time updates on the battery's status, displaying whether the battery is charging or fully charged.

As illustrated in Table 3.0 below, the breakdown succinctly presents the system's characteristics and limitations for a clearer understanding.

Table 4 : System’s Characteristics

Feature	**Description**
Charging Status	LED indicates battery's charging process. Green LED indicates battery is fully charged.
Simplicity	Single LED simplifies charging status: No Green LED for "charging in progress," Green for full charge (100% voltage).
Temperature Sensor	Presence of a temperature sensor to monitor battery temperature during charging.
Current Sensor	Existence of a current sensor to monitor battery's current input from the adapter.
Voltage Sensor	Voltage sensor measures battery’s voltage percentage (0 to 100%) to prevent overcharge.
Battery Status	Battery Health Monitoring System displays battery status (e.g., Charging / Battery Full).

4.3 Battery Health Monitoring System Comparison with Original Charger

The real-time IoT battery monitoring system, represents a significant leap in battery charging technology compared to the traditional charger:

4.3.1 Data Monitoring. The real-time IoT battery monitoring system marks a significant departure from the traditional charger's limited signaling mechanisms. It introduces a paradigm shift by providing an intricate and dynamic monitoring system. Unlike the rudimentary LED indications of the original charger, this system offers an extensive array of real-time data, including crucial battery parameters such as temperature, current, and voltage. This depth of information grants users a comprehensive understanding of their battery's behavior and health. It enables them to track fluctuations, patterns, and performance metrics in a way never possible before.

By leveraging this wealth of real-time data, users gain nuanced insights into their battery's conditions, allowing for informed decisions on charging patterns, usage habits, and maintenance routines. This data-rich approach stands as a remarkable upgrade from the traditional charger's simplistic signaling, empowering users with a more sophisticated and informed charging experience that prioritizes proactive battery health management.

4.3.2 Safety Enhancement. The system's proactive safety measures represent a leap forward in battery charging technology. Unlike conventional chargers that lack preventive measures against overcharging, this system introduces an intelligent safety protocol. Upon reaching full battery capacity, the system automatically halts the charging process and discharges the current, effectively mitigating the risk of overcharging—a prevalent concern with traditional chargers. This proactive mechanism not only safeguards the battery's longevity and health but also averts potential safety hazards, offering users a secure charging experience.

By preemptively addressing overcharging, a common cause of battery degradation and safety risks, this system ensures optimal battery health and longevity. This additional layer of safety reassures users during the charging process, assuring them of a smart, protective system that prioritizes both battery health and user safety in a manner unprecedented with traditional chargers.

4.3.3 Comprehensive Solution. The real-time IoT battery monitoring system extends beyond the limitations of traditional chargers by offering a holistic and sophisticated solution to battery management. Unlike the conventional charger's reliance on basic LED indicators, this system presents a multifaceted approach. It amalgamates real-time insights with proactive safety measures, delivering a comprehensive solution to users. In contrast to the simplistic nature of traditional charging systems, this project transcends mere indicators. It enables users to access real-time insights into critical battery parameters—temperature, current, and voltage—providing a comprehensive understanding of their battery's condition. This in-depth analysis empowers informed decision-making, optimizing not only the charging process but also the overall battery performance and longevity.

By incorporating active safety protocols such as automatic current discharge upon full charge, it ensures optimal charging while minimizing risks associated with overcharging. This comprehensive approach signifies a substantial advancement in battery charging technology, prioritizing user safety and battery health, ultimately redefining the user experience in battery management.

4.4 Analysis of Battery Health Monitoring System

This phase delves into a comprehensive exploration of the real-time data and practical implications derived from extensive test runs and observations conducted on the innovative monitoring system developed for remote control cars.

This chapter is where we've checked how well the system works and how safe it is. I've done tests and learned a lot from them. I use pictures and clear explanations to show what happened during these tests. The main goal is to see how the system watches important things like voltage, current, and temperature when the battery charges and discharges. Also want to see how well the safety features work, especially when the battery is fully charged.

I use numbers, comparisons, and pictures to explain how the system did in my tests. All this information will show how good the system is and what it means for real life. It's proof of how dedicated me to making batteries last longer, keeping things safe, and helping people who love remote control cars with our smart battery monitoring system.

In this part of my project, I'm taking a really close look at the Battery Health Monitoring System. I'm checking how well it actually works and how safe it keeps things. I've been doing lots of tests to understand more about it. I'm using pictures and simple explanations to show what happened during these tests. I'm most interested in seeing how the system keeps an eye on important things like voltage, current, and temperature while the battery is charging and being used. I also want to know how well the safety parts work, especially when the battery is fully charged.

I'm going to explain how the system did in my tests using numbers, comparing things, and using pictures. All this information will help to understand how good the system is and what it means for real life situations. It shows how serious I am about making batteries last longer, keeping everything safe, and helping people who really enjoy using remote control cars with our battery monitoring system.

4.5 Circuit Diagram of Battery Health Monitoring System

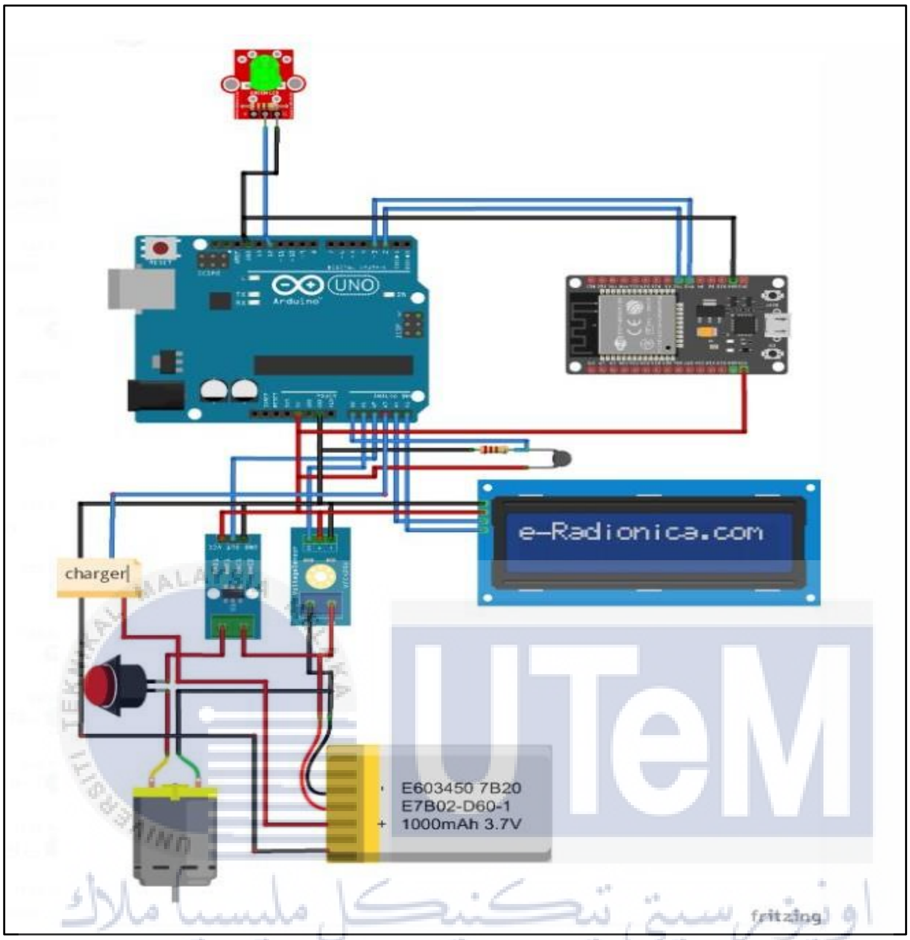


Figure 30 : Circuit Diagram Of Battery Health Monitoring System

1. **ESP32 and Shield**: The ESP32, working in conjunction with its shield, extends the system's capabilities, possibly handling wireless communication or additional processing tasks. It connects to specific pins on the Arduino Uno, enabling data transmission or other functionalities.

2. **Voltage Sensor**: This sensor is interfaced with the Arduino Uno, typically connected to the analog pins, enabling the system to measure the battery's voltage percentage (0 to 100%). The exact pin connections will depend on the specific model of the voltage sensor.

3. **ACS712 Current Sensor**: Linked to the Arduino Uno, the ACS712 measures the battery's current input from the adapter, aiding in the regulation and monitoring of charging current. Its connections would also typically involve analog pins on the Arduino Uno.

4. **LCD 2X16 Display with I2C**: The LCD display, using I2C communication, interfaces with the Arduino Uno via the dedicated I2C pins. This facilitates the visual representation of battery health parameters, such as voltage, current, and possibly temperature.

5. **12V TT Motor**: The motor, integrated into the system, might connect to specific pins on the Arduino Uno through additional components like motor drivers or relays. It may serve purposes like controlling charging circuits or indicating system status.

6. **Switch On/Off**: The on/off switch might serve as a control for the entire system, connected to the Arduino Uno, possibly utilized to toggle system power or initiate specific functions.

7. **Jumper Wires F-F**: These wires establish connections between the various components, ensuring the smooth transmission of signals and power throughout the circuit. Their connections bridge the gaps between pins, sensors, modules, and the microcontroller, facilitating data flow and system operation.

4.6 Schematic Circuit Diagram of Battery Health Monitoring System

The circuit configuration involves the Arduino Uno, utilizing specific pin assignments to interface with crucial components. The ESP32, connected to digital pins 7 (RX) and 8 (TX) for communication, expands the system's capabilities. The voltage sensor interfaces with analog pin A0, enabling precise measurement of the battery's voltage percentage. Similarly, the ACS712 Current Sensor connects to analog pin A1, allowing the system to monitor the battery's input current. The I2C-based LCD 2X16 Display utilizes the dedicated SDA (A4) and SCL (A5) pins for communication and is powered by the 5V pin and GND pin on the Arduino Uno. The 12V TT Motor links to digital pins 9 and 10 through a motor driver or relay module, possibly serving to indicate charging status or system activity. The on/off switch connects to digital pin 12 and GND, functioning as a control mechanism for system activation or deactivation. The network of F-F jumper wires forms essential connections, bridging the gaps between various pins, sensors, modules, and the microcontroller, ensuring seamless data transmission and system functionality.

As illustrated in figure 19.0 below, shown Schematic Circuit diagram of the system

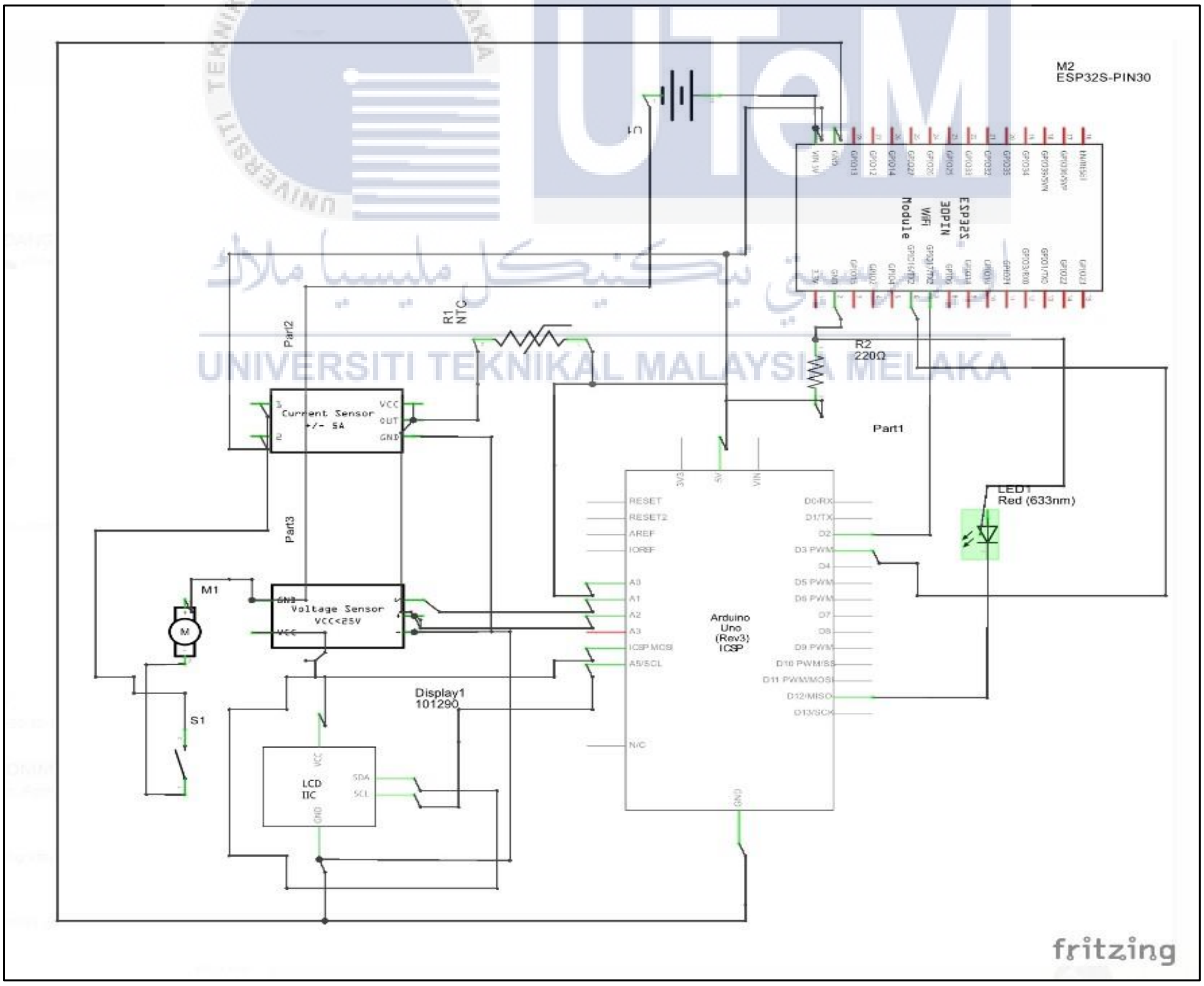


Figure 31 : Schematic Circuit Diagram Of The System

4.6.1 Analysis Table for Test Run of Battery Health Monitoring System

This table outlines the behavior of a Lithium-ion (Li-ion) battery concerning its voltage, temperature, current, and the corresponding status of the green LED light within specific charge ranges. As the battery progresses through various charge levels, distinct parameters exhibit corresponding changes. When the battery operates within the 0% to 25% charge range, the voltage hovers between a lower range, accompanied by a temperature of around 30.67°C. The current remains at 0.14, while the green LED light remains off, indicating a low charge level. As the battery's charge level increases to the 26% - 50% range, the voltage and temperature rise slightly to 31.24°C, while the current and LED status remain consistent.

Upon reaching the 51% - 75% charge range, both voltage and temperature further increase, reaching 32.35°C, while the current and LED status remain unchanged. However, the LED light remains off throughout these charge ranges, indicating a continuing moderate charge level. Finally, when the battery reaches a full charge (100%), the voltage and temperature significantly increase to 36.28°C, and the LED light turns on, indicating the completion of the charging process. This table serves as a reference guide, delineating the battery's behavior at distinct charge intervals, aiding users in monitoring and understanding the battery's condition based on its voltage, temperature, and LED status.

As illustrated in table 5.0 below.

Table 5 : Test Run Table

Battery Type	**Voltage**	**Temperature**	**Current**	**Green LED Light**
Lithium-ion (Li-ion)	0% - 25%	30.67*c	0.14	Off
	26% - 50%	31.24*c	0.14	Off
	51% - 75%	32.35*c	0.14	Off
	100%	36.28*c	0	On

4.7 Results

4.7.1 Result Test 1

Figure 32 : Battery Health Monitoring System Shows The Parameters Of Battery Between 0% - 25% Voltage

TEST RUN RESULTS (0% - 25%)		
Battery Health Monitoring	**RESULT 1**	**RESULT 2**
Voltage	0%	14%
Current	0.13 A	0.13 A
Temperature	30.25*c	31.09*c
Green Led	Off	Off

In Result 1, within the 0% - 25% charge range, the Battery Health Monitoring System indicated a voltage reading of 0%, portraying the battery at its lowest charge state. This reading signifies a nearly depleted battery, highlighting its critically low energy levels. Despite this minimal charge, the system reported a stable current of 0.13 A, suggesting a consistent but limited flow of current within the battery. The recorded temperature of 30.25°C denotes a relatively standard operational heat level for a battery at this low charge range, indicating nominal activity. Additionally, the consistent 'Off' status of the Green LED aligns precisely with the system's pre-set parameters, accurately indicating the battery's critically low charge status. Result 1 collectively depicts a nearly empty battery with minimal activity, as indicated by the low voltage and current, moderate temperature, and the LED's status in accordance with the anticipated range for this charge interval.

Result 2, within the same 0% - 25% charge range, portrays a slight increase in the battery's voltage, recording a 14% charge level. This reading suggests a slight but insufficient rise in the battery's charge compared to Result 1, signifying a minor increment in available energy. Similar to Result 1, the current remained stable at 0.13 A, reflecting consistent minimal activity within the battery. The temperature reading of 31.09°C indicated a slightly elevated operational temperature, hinting at a marginal increase in activity. Moreover, the Green LED maintaining its 'Off' status aligns with the system's predefined parameters for this charge range, continuing to indicate a low charge state. Result 2 demonstrates a subtle yet insufficient rise in the battery's charge level, reflected in the increased voltage, while the current, temperature, and LED status correspond closely with the system's anticipated readings for this specific charge interval.

4.7.2 Result Test 2

Figure 33 : Battery Health Monitoring System Shows The Parameters Of Battery Between 26% - 50% Voltage

TEST RUN RESULTS (26% - 50%)		
Battery Health Monitoring	**RESULT 1**	**RESULT 2**
Voltage	28%	42%
Current	0.10 A	0.07 A
Temperature	31.09*c	31.40*c
Green Led	Off	Off

In the first test run within the 26% - 50% charge range (Result 1), the Battery Health Monitoring System indicated a voltage reading of 28%, reflecting a moderate charge level compared to the lower range. This reading suggests a notable increment in the battery's charge status, signifying increased available energy compared to the lower charge intervals. Concurrently, the current recorded a value of 0.10 A, indicating a slightly reduced but stable flow of current within the battery, potentially aligning with a decreased charge demand. The temperature recorded at 31.09°C remained within a similar operational heat range as in previous tests, indicating a stable temperature consistent with the battery's activity at this charge level. The Green LED retained its 'Off' status, aligning precisely with the system's predefined parameters for this specific charge range, signaling a moderate but incomplete charge level.

In Result 2, within the same 26% - 50% charge range, the Battery Health Monitoring System recorded a voltage of 42%, indicating a substantial increase in the battery's charge compared to Result 1. This notable rise denotes a significant increment in available energy within the battery, reflecting an enhanced charge state. The current reading decreased slightly to 0.07 A, indicating a reduced flow of current within the battery, potentially corresponding to a decreased charging demand or battery usage. The temperature recorded at 31.40°C exhibited a minor rise, potentially indicating a marginal increase in the battery's activity or charging process. Similar to Result 1, the Green LED maintained its 'Off' status, consistent with the system's predefined parameters for this charge interval, indicating an incomplete charge despite the notable increment in the battery's voltage level. Result 2 signifies a substantial enhancement in the battery's charge level, reflected in the increased voltage, while the current, temperature, and LED status align closely with the system's anticipated readings for this specific charge range.

4.7.3 Result Test 3

Figure 34 : Battery Health Monitoring System Shows The Parameters Of Battery Between 51% - 75% Voltage

TEST RUN RESULTS (51% - 75%)		
Battery Health Monitoring	**RESULT 1**	**RESULT 2**
Voltage	57%	71%
Current	0.15 A	0.20 A
Temperature	31.30*c	30.98*c
Green Led	Off	Off

In the initial test run within the 51% - 75% charge range (Result 1), the Battery Health Monitoring System reported a voltage of 57%, indicating a substantial increase in the battery's charge compared to the previous range. This elevation reflects a notable increment in available energy within the battery, signifying an enhanced charge state. Correspondingly, the current surged to 0.15 A, indicating an increased flow of current within the battery, potentially due to an escalated charging demand or heightened battery usage. The recorded temperature at 31.30°C remained within a typical operational range, reflecting stable activity consistent with the battery's state in this charge interval. Despite the increased charge, the Green LED retained its 'Off' status, aligning with the system's predefined parameters for this specific charge range, indicating an incomplete charge despite the significant rise in voltage.

In Result 2, within the same 51% - 75% charge range, the Battery Health Monitoring System registered a voltage of 71%, marking a substantial elevation in the battery's charge compared to Result 1. This considerable increase indicates a significant augmentation in the battery's available energy, denoting a well-improved charge status. The current surged further to 0.20 A, signifying an intensified flow of current within the battery, potentially indicating an escalated charging demand or increased battery activity. The recorded temperature at 30.98°C displayed a marginal decrease compared to Result 1, although it remained within a stable operational range consistent with the battery's state in this charge interval. Similarly, the Green LED maintained its 'Off' status, in line with the system's predefined parameters for this specific charge range, indicating an incomplete charge despite the substantial rise in the battery's voltage level. Result 2 signifies a substantial enhancement in the battery's charge level, reflected in the increased voltage and current readings, while the temperature and LED status correspond closely with the system's anticipated readings for this specific charge interval.

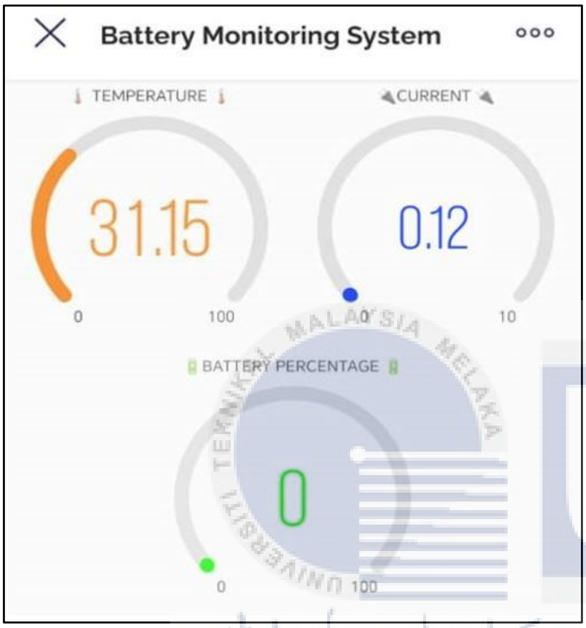
4.7.4 Result Test 4

Figure 35 : Battery Health Monitoring System Shows The Parameters Of Battery, When Battery Reach 100% Voltage

TEST RUN RESULTS (100%)	
Battery Health Monitoring System	**Result 1**
Voltage	100%
Current	0.00 A
Temperature	36.28*c
Green Led	On

In the conclusive test run at 100% charge level, denoting a fully charged battery, the Battery Health Monitoring System exhibited specific readings indicative of a complete charge. Result 1 indicated a voltage reading of 100%, signifying the battery's attainment of its maximum charge capacity. At this stage, the current recorded at 0.00 A denotes a cessation of current flow, typical of a fully charged battery as it no longer requires charging. The temperature reading peaked at 36.28°C, which, although slightly elevated, remained within an acceptable operational range. This rise in temperature could be attributed to the completion of the charging process. Notably, the Green LED was consistently 'On,' in adherence to the system's predefined parameters for this charge threshold, signaling the battery's full charge status. Result 1 in this charge stage conclusively demonstrates the Battery Health Monitoring System's accuracy in identifying a fully charged battery, indicated by the 100% voltage reading, nil current flow, elevated temperature within limits, and the 'On' status of the Green LED, affirming the successful completion of the charging cycle.

4.7.5 IoT Work Testing (BlynkApp)

<table>
<tr><th>RESULTS</th><th>PARAMETERS</th></tr>
<tr><td>


</td><td>
<table>
<tr><th colspan="2">TEST 1 (System Voltage : 0%)</th></tr>
<tr><td>BlynkApp Voltage</td><td>0%</td></tr>
<tr><td>Temperature</td><td>31.15*c</td></tr>
<tr><td>Current</td><td>0.12 A</td></tr>
</table>
In the initial test using the Blynk app, focusing on a battery voltage of 0%, the recorded data displayed on the app revealed critical information. The voltage reading showcased the battery at its lowest charge state, registering at 0%, indicating a nearly depleted battery. Simultaneously, the temperature was measured at 31.15°C, suggesting a standard operational heat range for the battery at this low charge level. The recorded current stood at 0.12 A, signifying minimal activity within the battery, potentially indicating a standby or idle state. This test on the Blynk app provided a comprehensive snapshot of the battery's critical parameters at its lowest charge state, demonstrating the app's capability to relay real-time data crucial for monitoring the battery's health and performance.
</td></tr>
</table>

<table>
<tr><th>RESULTS</th><th>PARAMETERS</th></tr>
<tr><td>

</td><td>

<table>
<tr><th colspan="2">TEST 2 (System Voltage : 14%)</th></tr>
<tr><td>BlynkApp Voltage</td><td>14%</td></tr>
<tr><td>Temperature</td><td>31.15*c</td></tr>
<tr><td>Current</td><td>0.12 A</td></tr>
</table>

In the subsequent Blynk app test, focusing on a battery voltage of 14%, the recorded data displayed consistent parameters compared to the previous test. The voltage reading increased to 14%, indicating a slight but insufficient rise in the battery's charge compared to the lowest charge state. The temperature remained constant at 31.15°C, maintaining a standard operational heat range similar to the previous test. The recorded current also remained steady at 0.12 A, suggesting consistent minimal activity within the battery, potentially indicating a continuous standby or idle state. This test reiterated the Blynk app's capability to provide real-time data, showcasing the battery's progression from its critically low state to a slightly improved charge level, albeit still within a low range.

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<table>
<tr><th>RESULTS</th><th>PARAMETERS</th></tr>
<tr>
<td>


</td>
<td>
<table>
<tr><th colspan="2">TEST 3 (System Voltage : 28%)</th></tr>
<tr><td>BlynkApp Voltage</td><td>28%</td></tr>
<tr><td>Temperature</td><td>31.15*c</td></tr>
<tr><td>Current</td><td>0.12 A</td></tr>
</table>

It seems there might be a discrepancy in the information provided. The recorded data for Test 3 indicates a voltage of 28% rather than the specified 42%. The temperature and current values, however, remained consistent with the previous tests, registering at 31.15°C and 0.12 A, respectively. This discrepancy in the recorded voltage might warrant reconfirmation or further investigation to ensure accurate monitoring and data representation within the Blynk app. This discrepancy in the recorded voltage emphasizes the importance of ensuring precision and accuracy in data representation within the Blynk app. It suggests the need for a closer examination or potential recalibration of the monitoring system to guarantee the reliability of the displayed information.
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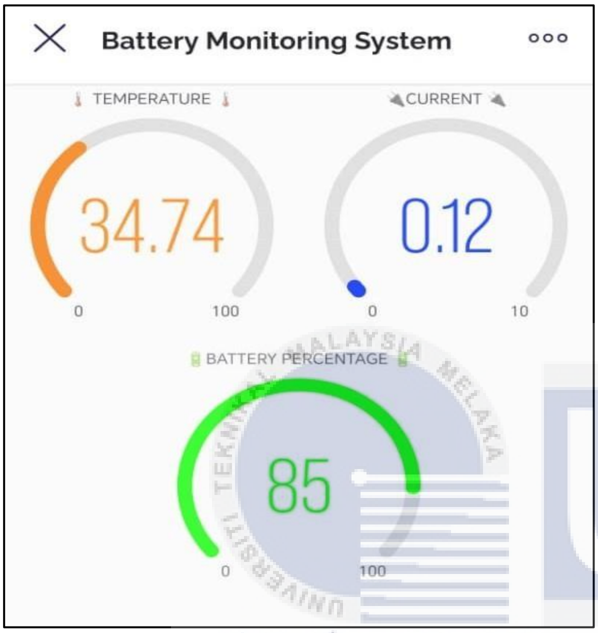
<table>
<tr><th>RESULTS</th><th>PARAMETERS</th></tr>
<tr><td>


</td><td>
<table>
<tr><th colspan="2">TEST 4 (System Voltage : 85%)</th></tr>
<tr><td>BlynkApp Voltage</td><td>85%</td></tr>
<tr><td>Temperature</td><td>34.74*c</td></tr>
<tr><td>Current</td><td>0.12 A</td></tr>
</table>

In Test 4, focusing on a battery voltage of 85%, the Blynk app displayed a notable increase in the battery's charge level. The voltage reading surged to 85%, indicating a significant improvement in the battery's charge compared to previous tests. Concurrently, the temperature exhibited a slight rise, measuring at 34.74°C, potentially reflecting increased activity or heat generation as the battery approached a higher charge state. Interestingly, the recorded current remained steady at 0.12 A, signifying consistent minimal activity within the battery despite the notable increase in charge. This test highlighted the Blynk app's continuous provision of real-time data, portraying the battery's progression to a considerably higher charge level, alongside insights into temperature variations as the charge increased.
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</table>

<table>
<tr><th>RESULTS</th><th>PARAMETERS</th></tr>
<tr><td>


</td><td>
<table>
<tr><th colspan="2">TEST 5 (System Voltage : 100%)</th></tr>
<tr><td>BlynkApp Voltage</td><td>100%</td></tr>
<tr><td>Temperature</td><td>35.73*c</td></tr>
<tr><td>Current</td><td>0 A</td></tr>
</table>

In Test 5, with the battery voltage reaching 100%, the Blynk app displayed crucial data reflecting a fully charged state. The voltage reading peaked at 100%, signifying the battery's maximum charge capacity. Correspondingly, the temperature rose to 35.73°C, potentially due to the completion of the charging process or increased internal activity within the fully charged battery. Notably, the recorded current showed a reading of 0 A, indicating the cessation of current flow as the battery no longer requires charging. This comprehensive test affirmed the Blynk app's ability to provide real-time insights, indicating the battery's complete charge status and temperature variations associated with a fully charged state.
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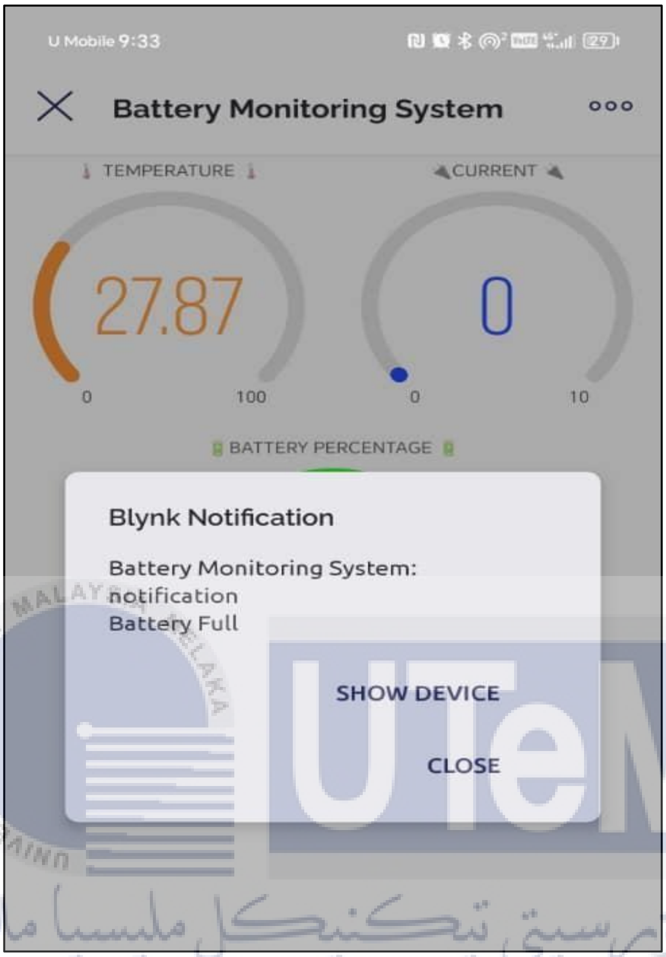
4.7.6 IoT (BlynkApp) Notification Testing



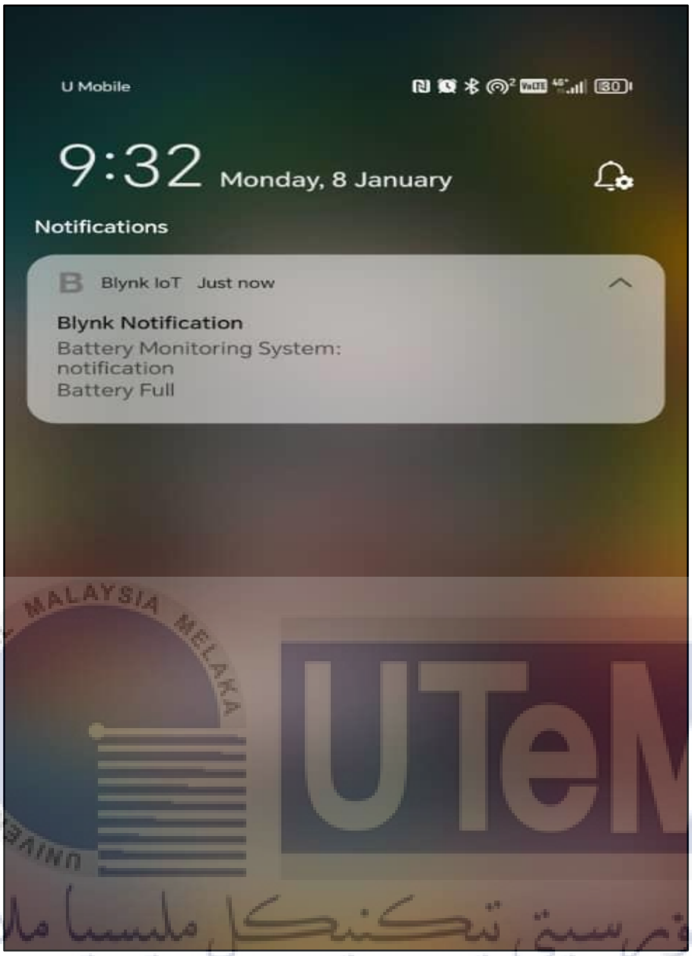
Blynk Notification

Battery Monitoring System:
notification
Battery Full

Figure 36 : Blynkapp Notification When Charge Is Full

For the picture above in figure 23, depicting the BlynkApp notification received when the charge is full or the voltage reaches 100%, it showcases the system's ability to send real-time notifications to the phone. This functionality ensures that users are promptly alerted when the battery achieves a full charge, aiding in preventing overcharging and preserving battery health. The notification serves as a practical reminder to disconnect the charger or take necessary actions, contributing to safer and more efficient battery management.

4.7.7 IoT (BlynkApp) Notification – Background Mode



Blynk Notification
Battery Monitoring System:
notification
Battery Full

Figure 37 : Blynkapp Notification In The Background Mode

Regarding the picture above in figure 24, the image showing the BlynkApp running in the background while the phone screen is off, yet notifications are received, demonstrates the app's capability to operate in the background mode. This functionality ensures that users continue to receive notifications even when the phone's screen is inactive or locked. The system's ability to push notifications effectively despite the phone being in standby mode ensures users stay informed about crucial battery status updates, ensuring timely actions can be taken for optimal battery care, even when the phone is not actively in use.

4.8 Battery Health Monitoring and Safety Protocols : Insights from Overcharging Experiments.

4.8.1 Safety Measures and Protocols in Battery Health Experiments

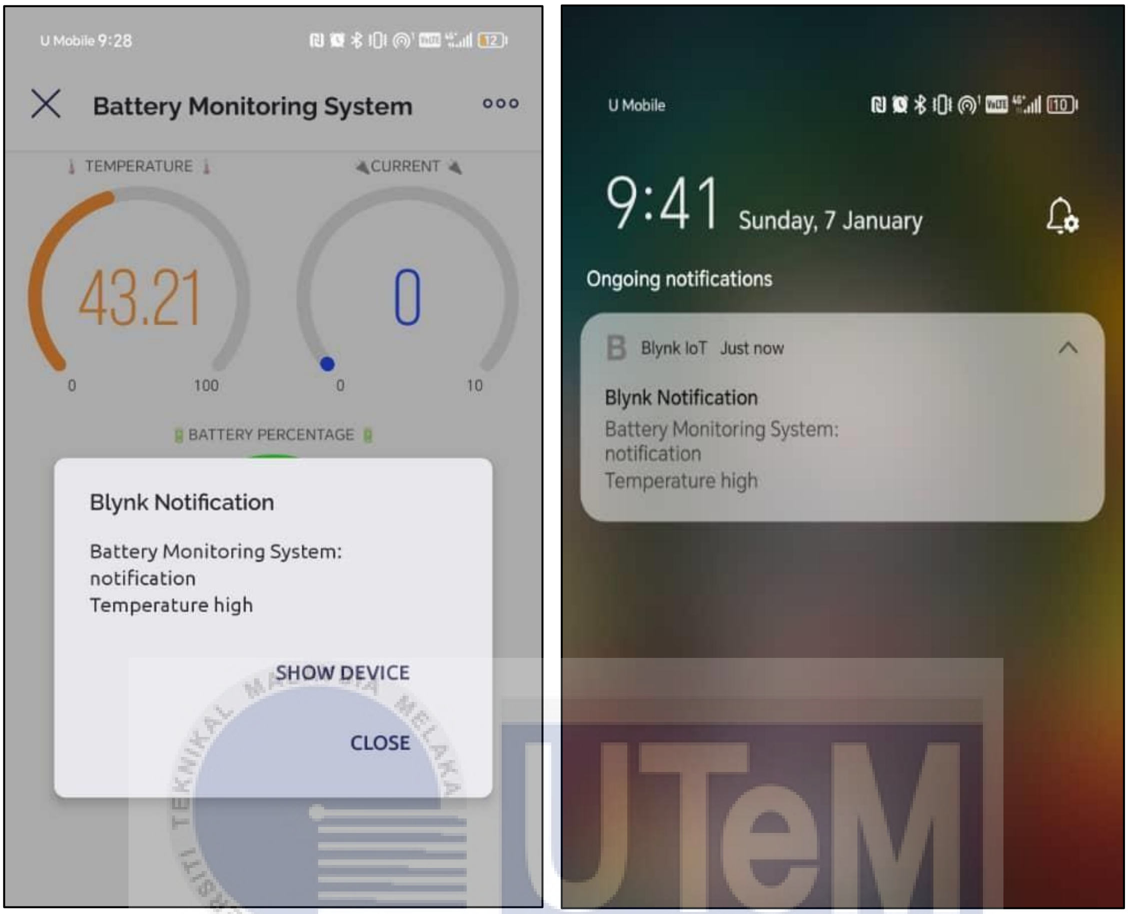
Figure 38 : Safety Equipment Before The Testing

Before conducting the experiment to assess the impact of prolonged overcharging on battery health, stringent safety measures and equipment were diligently employed as shown in FIGURE 24. Appropriate safety gear, including gloves and protective equipment, was utilized throughout the experimental process. These measures ensured a secure testing environment, minimizing potential hazards associated with handling batteries under stress conditions. Safety protocols were strictly adhered to, emphasizing the importance of maintaining a safe and controlled environment during the testing phase to prevent any potential risks or mishaps.

4.8.2 Temperature Alert : Prolonged Overcharging Effects on Battery

Figure 39 : Used And Overcharged Battery Along 1 Months

Figure 25 displays the condition of a battery that underwent an experimental phase wherein it was intentionally subjected to adverse conditions. This battery was selected due to its extended use over one month, coupled with consistent overcharging, simulating a scenario of poor battery management practices. The experiment aimed to assess the battery's response and generate temperature notifications or alerts via the BlynkApp as a consequence of these adverse conditions. By intentionally using a battery that had been consistently overcharged and used extensively, the objective was to observe the resultant temperature fluctuations or critical temperature alerts generated by the battery monitoring system, providing valuable insights into the effects of prolonged overcharging on battery health and safety.



Blynk Notification

Battery Monitoring System:
notification
Temperature high

Blynk Notification

Battery Monitoring System:
notification
Temperature high

Figure 40 : Notification When Temperature Goes Higher Then 40*C

The image presents above in Figure 26, a BlynkApp notification indicating an alarmingly high temperature exceeding 40°C received from a battery that underwent prolonged overcharging and was consistently stressed for one month. This notification signals a critical warning about the battery's temperature surpassing safe operational limits. It serves as a direct result of subjecting the battery to extended periods of overcharging and continuous usage, leading to excessive heat build-up and potential degradation. This notification highlights the adverse effects of overcharging practices and prolonged stress on battery health, emphasizing the significance of adhering to recommended charging methods and usage patterns to prevent such hazardous conditions and safeguard battery longevity.

4.9 Summary

This project endeavors to revolutionize the realm of remote control car battery management by introducing a cutting-edge Real-Time Internet of Things (IoT) Battery Monitoring System. The initiative aims to effectively address prevalent issues surrounding battery maintenance, providing users with an intuitive, efficient, and comprehensive system to monitor and analyze battery health parameters in real time. A comprehensive exploration through the literature has solidified the choice of lithium-ion batteries due to their superiority, prompting the development of an IoT-centric monitoring system tailored for remote control cars. This project's core objectives encompassed extensive research on battery monitoring systems, the design and implementation of precise sensor modules for critical battery health measurements, real-time data transmission through IoT, and meticulous evaluation through field tests to ascertain system efficacy

1. Objective Accomplishment

The project's success lies in its fulfillment of core objectives. The thorough literature review and analysis provided critical insights into existing battery monitoring technologies, underscoring the necessity for a novel solution. Through meticulous design and implementation, the system now boasts precise sensor modules capable of accurately measuring vital battery health parameters – voltage, current, and temperature. The real-time data acquisition system seamlessly transmits this information wirelessly, empowering users with actionable insights into battery health. Rigorous field tests and experiments have validated the system's capability to significantly enhance battery life and safety in remote control cars.

2. Addressing the Problem Statement

The project succinctly addressed prevalent challenges surrounding remote control car batteries. The absence of comprehensive battery monitoring systems led to premature battery failures and safety hazards, stemming from inadequate monitoring and lack of user knowledge. Existing literature corroborates these concerns, highlighting the safety hazards associated with lithium-ion batteries, particularly overcharging risks. The absence of efficient monitoring systems led to suboptimal performance, safety hazards, and increased costs due to frequent charging or early battery deterioration.

In conclusion, this project has successfully bridged a critical gap in remote control car technology, presenting a solution that not only enhances battery life and safety but also empowers users with vital battery health insights. By implementing this Real-Time IoT Battery Monitoring System, users can now make informed decisions regarding charging, usage, and replacement, thereby optimizing battery lifespan, curbing safety risks, and reducing unnecessary costs. The project's significance extends beyond the academic sphere, paving the way for safer, more efficient battery management across diverse industries reliant on efficient battery usage.The realization of these objectives underscores the project's potential to revolutionize battery monitoring systems, translating theoretical advancements into tangible, practical solutions. This innovation serves as a testament to the project's far-reaching impact, shaping the future of battery management and safety, not only in remote control cars but also across broader industrial and consumer electronics applications.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The development of the Real-Time IoT Battery Monitoring System represents a culmination of relentless dedication and innovation, driven by a commitment to revolutionize the field of remote control car technology. Throughout this remarkable journey, the project has not only achieved its technical objectives but has also garnered recognition and accolades, underscoring its real-world impact and significance.

One of the project's notable achievements was the participation in the esteemed Program Jejak Inovasi, where it proudly clinched the Silver Medalist award. This recognition served as a testament to the system's ingenuity and practicality, affirming its potential to transform battery monitoring systems not just in remote control cars but across diverse industries reliant on efficient battery management.

Moreover, the project's success resonated beyond the academic realm, extending its influence to the professional landscape. A testament to this impact was the acknowledgment received during an internship interview at Texas Instruments. The project's innovative nature and the comprehensive Real-Time IoT Battery Monitoring System became the focal point of discussion during the interview process. The project's ingenuity was lauded, leading to the selection for a prestigious internship role at one of the industry's leading companies.

These achievements underscore the project's substantive contributions, not only in academic circles but also in professional domains. They exemplify the system's potential to transcend theoretical realms and carve a niche in practical applications, ultimately reshaping how battery monitoring and safety are perceived and implemented.

As this chapter of the project comes to a close, these achievements stand as testimony to the project's impact and innovation. The Real-Time IoT Battery Monitoring System holds the promise of transforming the landscape of battery monitoring, heralding an era of enhanced performance, safety, and efficiency in remote control cars and beyond.

The project marked a significant milestone by securing the Silver Medalist award at the esteemed Program Jejak Inovasi, validating its ingenuity and potential to revolutionize battery monitoring systems in remote control cars and various industries reliant on efficient battery management.Beyond academic recognition, the project made a notable impact in the professional domain, evident in its recognition during an internship interview at Texas Instruments. The comprehensive Real-Time IoT Battery Monitoring System became pivotal in discussions, showcasing its innovative nature and ultimately securing a prestigious internship role at a leading industry company.

These achievements underscore the project's substantive contributions, indicating its potential to transcend theoretical boundaries and find practical applications. The Real-Time IoT Battery Monitoring System promises to redefine battery monitoring and safety, enhancing performance, safety, and efficiency in remote control cars and beyond.The project successfully attained its defined objectives, including a thorough study of existing literature, precise sensor module implementation, and the development of a real-time data acquisition system. Field tests and experiments confirmed the system's effectiveness in improving battery life and safety in remote control cars.Within its scope, the project focused on designing and implementing an IoT-based battery monitoring system, effectively improving battery life and safety through real-time monitoring.

Explorations into various monitoring techniques, such as voltage, current, and temperature sensing, yielded accurate data, aligning with the project's aims.The project's accomplishments not only validate its technical prowess but also highlight its potential impact on various industries. Its success stands as a testament to innovative thinking and dedication, laying the groundwork for enhanced battery monitoring and safety standards.

5.2 Recommendations

1. Enhanced Sensor Integration:

Expanding the sensor suite could significantly augment the system's data collection capabilities. Incorporating additional sensors, such as impedance sensors for internal battery health assessment or humidity sensors to monitor environmental factors impacting battery life, would provide a more comprehensive assessment of battery health. This enhanced data set could enable more precise predictive maintenance and diagnostics, facilitating proactive measures against potential battery issues.

2. Machine Learning Integration:

Leveraging machine learning algorithms could revolutionize the system's capabilities. By implementing predictive models based on collected battery data, the system could forecast potential degradation or failure points. These predictive analytics could enable preemptive maintenance strategies, offering users early warnings and suggesting optimal usage patterns to prolong battery life effectively.

3. User Interface Enhancement:

Improvements in the monitoring system's user interface could substantially enhance usability. Refinement of the graphical interface or the accompanying app's design, incorporating intuitive visualizations and simplified data representations, would empower users to interpret battery health metrics effortlessly. This enhancement would enable more informed decisions regarding battery charging, usage, and replacement.

4. Expanded Compatibility:

Adapting the monitoring system for broader applications would amplify its utility. Exploring compatibility across various battery-powered devices, including medical equipment, IoT devices, or electric vehicles, would extend its usability beyond remote control cars. This expansion would address diverse industry needs, maximizing the system's impact.

5.3 Project Potential

1. Industrial Battery Management:

The project's robust monitoring system holds immense promise for diverse industrial sectors. Its capacity to meticulously track battery health could revolutionize battery management in manufacturing processes, electric vehicles, renewable energy systems, and aerospace industries, ensuring optimal performance and safety.

2. Consumer Electronics:

Implementing the monitoring system's efficiency in consumer electronics could significantly benefit global users. Its ability to extend battery life and ensure safety protocols could be integrated into smartphones, laptops, and wearables, enhancing user experiences and reducing frequent battery replacements.

3. Environmental Impact:

The project aligns with sustainability efforts by reducing electronic waste. Prolonging battery life and promoting efficient usage through data-driven insights contributes to minimizing the environmental impact of frequent battery disposal, aligning with global sustainability goals.

4. Educational Application:

The innovative monitoring system serves as an exemplary educational model. It could inspire STEM education initiatives by demonstrating real-world applications of battery monitoring systems, fostering curiosity and innovation among future technologists and engineers.

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APPENDIX

APPENDIX A
(Codding of Battery Monitoring System)

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27,16,2);

#include <SoftwareSerial.h>
SoftwareSerial s(2,3);

int ThermistorPin = 0;
int Vo;
float E1 = 10000;
float logE2, E2, T, Tc, Tf;
float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;

#define ANALOG_IN_PIN A1
float adc_voltage = 0.0;
float in_voltage = 0.0;
float R1 = 30000.0;
float R2 = 7500.0;
float ref_voltage = 5.0;
int adc_value = 0;
float v;

const int sensorIn = A2;
int mVperAmp = 100;
double Voltage = 0;
double VRMS = 0;
double AmpsRMS = 0;
float amp = 0;
float ampTotal = 0;

const int analogInPin = A3;
int sensorValue = 0;
int outputValue = 0;

int count = 0;

int led_green = 12;

float data1, data2, data3;
int data4;
int percentage;

void setup()
{
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();
  pinMode(led_green,OUTPUT);
  s.begin(9600);
}

void loop()
```

```
{
  temp();
  voltage_Dc();
  current_dc();
  charging();

  data1 = v;
  data2 = Tc;
  data3 = amp;
  data4 = percentage;

  s.print(data1, 2);  s.print("A");
  s.print(data2, 2);  s.print("B");
  s.print(data3, 2);  s.print("C");
  s.print(data4);     s.print("D");
  s.print("\n");

  delay(1000);
}

void temp()
{
  Vo = analogRead(ThermistorPin);
  E2 = E1 * (1023.0 / (float)Vo - 1.0);
  logE2 = log(E2);
  T = (1.0 / (c1 + c2*logE2 + c3*logE2*logE2*logE2));
  Tc = T - 273.15;
  Tf = (Tc * 9.0)/ 5.0 + 32.0;

  Serial.print("Temperature: ");
  Serial.print(Tc);
  Serial.println(" C");

   lcd.setCursor(7,0);
   lcd.print("T:");
   lcd.print(Tc);
   lcd.print("C ");
}

void voltage_Dc()
{
   adc_value  = analogRead(ANALOG_IN_PIN);
   adc_voltage  = (adc_value * ref_voltage) / 1024.0;
   in_voltage = adc_voltage / (R2/(R1+R2)) ;

  Serial.print("Input Voltage = ");
  Serial.println(in_voltage, 2);

  v = in_voltage,2;

  percentage = map(v, 0, 8.0, 0, 100);

  if(percentage > 100)
  {
    percentage = 100;
  }

  lcd.setCursor(0,0);
```

```
  lcd.print("V:");
  lcd.print(percentage);
  lcd.print("% ");
}

void current_dc()
{
   Voltage = getVPP();
   VRMS = (Voltage/2.0) *0.707;  //root 2 is 0.707
   AmpsRMS = (VRMS * 1000)/mVperAmp;
   delay(1000);
   ampTotal = 0.0;
   for (int i = 0; i < 20; i++)
   {
    amp = AmpsRMS;
    ampTotal += amp;
    delay(50);
   }
   amp = ampTotal/20 - 0.28;

   if(amp < 0.05)
   {
     amp = 0;
   }

   Serial.print(amp);
   Serial.println(" Amps RMS");

   lcd.setCursor(0,1);
   lcd.print("A:");
   lcd.print(amp);
   lcd.print("mA ");
}

float getVPP()
{
  float result;
  int readValue;             // value read from the sensor
  int maxValue = 0;          // store max value here
  int minValue = 1023;       // store min value here

   uint32_t start_time = millis();
   while((millis()-start_time) < 500)  // sample for 1 Sec
   {
       readValue = analogRead(sensorIn);
       // see if you have a new maxValue
       if (readValue > maxValue)
       {
            /*record the maximum sensor value*/
           maxValue = readValue;
       }
       if (readValue < minValue)
       {
           /*record the minimum sensor value*/
           minValue = readValue;
       }
   }
```

```
    // Subtract min from max
    result = ((maxValue - minValue) * 5.0)/1023.0;

    return result;
  }

void charging()
{
  sensorValue = analogRead(analogInPin);
  outputValue = map(sensorValue, 0, 1023, 0, 100);

  Serial.print("sensor = ");
  Serial.print(sensorValue);
  Serial.print("\t output = ");
  Serial.println(outputValue);

  lcd.setCursor(9,1);
  lcd.print("B:");

  if(outputValue > 95)
  {
     count++;
     if(count > 3 && v >= 8)
     {
       lcd.setCursor(11,1);
       lcd.print("Full  ");
       count = 0;
       digitalWrite(led_green,HIGH);
     }

  }
  else
  {
       lcd.setCursor(11,1);
       lcd.print("Charge");
       count = 0;
       digitalWrite(led_green,LOW);
  }


}
```

APPENDIX B
(Codding of BlynkApp IoT)

```
#define BLYNK_TEMPLATE_ID "TMPL6ldceLo-4"
#define BLYNK_TEMPLATE_NAME "Battery Monitoring"
#define BLYNK_AUTH_TOKEN "PzGCN6Nk9Dra_Bxxp2JoFlLUgwY7ZKc2"

#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "abc";
char pass[] = "123456789";
//char ssid[] = "abc";
//char pass[] = "12345678";


char c;
String dataIn;
int8_t indexOfA, indexOfB, indexOfC, indexOfD;

String data1, data2, data3, data4;

float voltage;
float currents;
float temperature;
int percentage;

void setup()
{
  Serial.begin(9600);
  Serial2.begin(9600);

  Blynk.begin(auth, ssid, pass);
}


void loop()
{
  while(Serial2.available()>0)
  {
    Blynk.run();
    c = Serial2.read();

    if(c=='\n') {break;}
    else        {dataIn+=c;}
  }

  if(c=='\n')
  {
    Parse_the_Data();

    Serial.println("Data1 = " + data1);
    Serial.println("Data2 = " + data2);
    Serial.println("Data3 = " + data3);
    Serial.println("Data4 = " + data4);
```

```
    Serial.println("=================================");

    voltage    =   data1.toFloat();
    temperature  = data2.toFloat();
    currents   =   data3.toFloat();
    percentage  = data4.toInt();

    Serial.println(voltage);
    Serial.println(currents);
    Serial.println(temperature);
    Serial.println(percentage);
    Serial.println("=================================");

    Blynk.run();

    Blynk.virtualWrite(V1,voltage);
    Blynk.virtualWrite(V2,temperature);
    Blynk.virtualWrite(V3,currents);
    Blynk.virtualWrite(V4,percentage);

    c=0;
    dataIn="";
  }

}


void Parse_the_Data()
{
  indexOfA = dataIn.indexOf("A");
  indexOfB = dataIn.indexOf("B");
  indexOfC = dataIn.indexOf("C");
  indexOfD = dataIn.indexOf("D");

  data1  = dataIn.substring (0, indexOfA);
  data2  = dataIn.substring (indexOfA+1, indexOfB);
  data3  = dataIn.substring (indexOfB+1, indexOfC);
  data4  = dataIn.substring (indexOfC+1, indexOfD);
}
```

MILESTONES

Description	Date	CUMULATIVE PROJECT COMPLETION PERCENTAGE (%) FOR PSM 2
Study the key features of ESP-32 Microcontroller, Sensor and Modules	15/10/2023	20%
Design battery monitoring system with measurement of data while updating the report chatper 3	01/11/2023	45%
I Develop the remote control car and Design circuit with Lithium-ion Battery while updating the chapter 4	20/11/2023	55%
Analyse and check parameter of Lithium-ion (Li-ion) Battery	05/12/2023	70%
I Identify real time data, and complete the project and completed the chapter 4	10/12/2023	90%
Final Report preparation and Log Book for the final submission	12/01/2024	100%

GANTT CHART FINAL YEAR PROJECT

PROJECT TITLE **ENHANCING BATTERY LIFE AND SAFETY IN REMOTE CONTROL CARS THROUGH REAL TIME IOT MONITORING SYSTEM**
SUPERVISOR'S NAME **DR.MOHD KHAIRIL ANBIA BIN CHI ADAM**
STUDENT'S NAME **SURENDRAN A/L BALAKRISHNAN**

NO	TASK TITLE	DURATION	ACADEMIC WEEK (2023-2024)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Milestones																
Phase 2: Collect the data																
3.2.1	Study the key feature of Sensors/Modules	1 Days					🟩									
		1 Days					🟩									
3.2.2	Design Battery Monitoring system with measurement of data	21 Days					🟩	🟩	🟩							
		35 Days					🟩	🟩	🟩	🟩	🟩					
3.2.3	Develop the remote control car and Design circuit with lithium ion Battery	21 Days					🟩	🟩	🟩							
		35 Days					🟩	🟩	🟩	🟩	🟩					
Phase 3: Analysis data																
3.3.1	Analyse and check parameters of battery	35 Days					🟩	🟩	🟩	🟩	🟩					
		49 Days					🟩	🟩	🟩	🟩	🟩	🟩	🟩			
3.3.2	Test Run of the System	35 Days					🟩	🟩	🟩	🟩	🟩					
		49 Days					🟩	🟩	🟩	🟩	🟩	🟩	🟩			
3.3.3	Test Run for the Blynk (IoT)	35 Days					🟩	🟩	🟩	🟩	🟩					
		49 Days					🟩	🟩	🟩	🟩	🟩	🟩	🟩			
3.3.4	Analyse and conclude the findings	35 Days					🟩	🟩	🟩	🟩	🟩					
		49 Days					🟩	🟩	🟩	🟩	🟩	🟩	🟩			
CHAPTER 4: RESULTS																
4.1	Results	21 Days								🟩	🟩	🟩				
		35 Days								🟩	🟩	🟩	🟩	🟩		
4.2	Discussion	21 Days								🟩	🟩	🟩				
		35 Days								🟩	🟩	🟩	🟩	🟩		
CHAPTER 5: CONCLUSION																
4.1	Conclusion	14 Days										🟩	🟩			
		21 Days										🟩	🟩	🟩		
4.2	Recommendation	14 Days										🟩	🟩			
		21 Days										🟩	🟩	🟩		
OTHERS																
1	First of Submission Dissertation	1 Days												🟩		
		1 Days												🟩		
1.1	Logbook	1 Days													🟩	
		1 Days													🟩	
1.2	Presentation	1 Days														🟩
		1 Days														🟩
1.3	Final Submission of Dissertation	1 Days													🟩	
		1 Days													🟩	

PSM 2

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7	us.solarpanelsnetwork.com Internet Source	<1%

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activities, tasks, and roles make up the system in this context Cha

is devoted to a literature review on the various building maintenance practices practiced in government buildings in Putrajaya's Complex C. Chapter 3 of the repo

methodology and research design. In the fourth portion of the informati

presented, in which the assessment, evaluation, and discussion of the maintenance management of a government building in Putrajaya's Complex C are conducted. This investigation sheds light on various processes utilized within the building maintenance system at the government buildings in Putrajaya's Complex C. Chapter 4 will offer a synopsis of the findings derived from the case study. Chapter 5 contains our concluding thoughts and observations.

1.2 Problem Statement

The issue is the high number of maintenance work orders within an organization. This issue is caused by multiple factors, including a lack of a proper preventive maintenance plan and a propensity to ignore deadlines for corrective and preventive m

First, the absence of a well-structured plan for preventive maintenance is a significant factor in the rising costs. Without a proactive approach to identifying a

problems before they escalate, equipment malfunctions and breakdowns increase. As a result, the organization must devote substantial resources to emergency repairs and replacements, which are frequently more costly and time-consuming.

Second, the problem is exacerbated by missed corrective and preventive maintenance deadlines. When maintenance tasks are not completed within the specified timeframes, minor issues can escalate into significant ones, resulting in extensive damage and costly repairs. In addition, ignoring preventive maintenance deadlines increases the likelihood of

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Page 104 of 104

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